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GASOLENE ENGINES
THEIR OPERATION, USE AND CARE

A COMPREHENSIVE, SIMPLE AND PRACTICAL WORK

Treating of Gasolene Engines for Stationary, Marine or Vehicle Use. Their Construction, Design, Management, Care, Operation, Repair, Installation and Troubles.

Written especially for the Owner, Operator or Purchaser of Gasolene Motors who is unfamiliar with Technicalities and is not a mechanic or engineer. A book that is indispensable to the Amateur and of value to the Professional.

Containing also a complete table of Motor Troubles and Remedies and a full Glossary of Technical Terms used in Connection with Gasolene Engines.

Alpheus

By A. HYATT VERRILL

Fully Illustrated with 152 Original Engravings

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PREFACE

In the preparation of this work the author has endeavored to produce a book which will serve as a practical guide and handbook to all those who at any time have occasion to use or operate gasolene engines. It is particularly intended for those with little or no knowledge of mechanics or engineering, and with this purpose in view technical terms and names have been practically eliminated from the text and descriptions, and explanations have been made as clear and plain as possible and as concise as a full explanation will admit. As technicalities cannot be entirely avoided in any work dealing with machinery, a full glossary of such terms, as applied to gasolene motors, has been added to the work, and the reader who is without any knowledge whatever of machinists' and engineers' terms will find in this feature a ready reference and explanation.

Appreciating the value of illustrations as an aid to text description, the author has endeavored to figure each and every part and feature treated in the work; and in order to make the illustrations more plain and understandable every part or portion not directly related to the point under discussion has been eliminated in the figures.

The illustrations are in no sense working drawings, but are mainly diagrammatic, and no attempt has been made to draw them to accurate scale, while in order to bring out certain features of construction or operation such features have been purposely exaggerated. This is the case with the tapered shafts on page 96, as well as with the pitch of various screw threads and gear teeth. This may be wrong theoretically, but in serving its purpose it is good practically, which is exactly the reverse of many theories in mechanics and engineering.

While volumes might be devoted to enumerating and describing *all* the troubles which *might* occur in gasolene-engine operation, yet the number that are likely to be met are comparatively few and are fully covered in the alphabetically arranged table of troubles in the work.

The plain and simple tables of screw threads, pipe sizes, etc., will, it is hoped, prove of value, especially to those having occasion to replace or order fittings or screws.

The chapter on useful hints and makeshift repairs has been compiled from actual experience and each has been tried and tested many times in real practice.

The author sincerely hopes that the work will prove as useful and valuable to all his readers as a similar work would have been to him in the early years of his gasolene-motor experiences.

September, 1912.

INTRODUCTION

THE discovery of the Gas Engine marked a new era in mechanical progress and its perfection has led to some of the most marvellous and important of modern inventions and achievements.

Through its use aëroplanes and submarines have become possible, and motor vehicles of all kinds depend largely upon the gasolene engine for power; while motor boats, launches, and power cruisers have placed yachting within reach of the man of moderate means, whereas a few years ago the use of steam confined this pleasure to the wealthy few.

Useful and important as the gas motor has proved for vehicle and marine use, even more valuable are its services in stationary form. In factory, home, and farm the stationary gasolene engine is in daily use, performing steadily and easily the work of many hands at a fraction of the cost of the old steam engine. On the farm especially has the explosive motor proven its worth, and this light, simple, portable power-plant has revolutionized farm work in many sections. Labor that was formerly slow and irksome is now performed easily, quickly, and pleasurably and the ingenious farmer finds a thousand and one uses for his motor. It will separate his cream, turn his grindstone, do the wife's washing, and light the home with *electricity*; and if mounted on a "tractor" it will plough and harrow the fields, plant and cultivate the crops, and will mow, thresh, and grind the grain.

When we consider the manifold uses of the gas engine and the number in daily use it seems surprising that so few owners, operators, or users thoroughly understand their engines or their construction, operation, or care. Many a man who would feel incompetent to operate a steam engine will undertake to handle a large or complicated gas engine; and yet, as a matter of fact, the latter is by far the more delicate piece of mechanism. It certainly speaks well for the modern gas motor that, under the ordinary conditions and in the hands of so many people absolutely ignorant of the first principles of engineering or mechanics, there is so little trouble. It is no uncommon thing to hear the owner of a gasolene engine boast that his motor has run so many miles or so many hours without missing an explosion. Did you ever hear a steam-engineer boast that *his* engine had run a few hours or a few days without blowing up the boiler or bursting a cylinder?—and yet there is as much reason for one as for the other. If a gas motor is properly adjusted and runs smoothly for an hour there is no earthly reason why it should not continue to run for days, months, or years, as long as it is fed fuel, lubricating oil, and electric current, and ordinary wear and tear are attended to, as in any other piece of machinery.

The idea that a gas engine must give trouble, that it is an obstinate and balky thing, and that it will fail at the most critical time without cause is pure nonsense. If a gas engine fails to operate there is some good and *sufficient reason;* for the modern gas engine is no longer an experiment, made by guess and by hand, but is a thoroughly well made, carefully designed, and well tested mechanical device; but like any other machine, to operate successfully, it *must* be given certain conditions. Nine times out of ten the "balkiness and obstinacy" are in the operator and not in the motor, and a little common sense and judgment will do far more than a lot of swearing, cranking, and hit-or-miss adjusting.

One often sees a man operating a motor, which is running smoothly and well, continually loosening a nut or screw here and tightening there, or fooling with some part or another of his engine. This practice is sure to cause trouble and sooner or later the motor skips and stops. Being perfectly ignorant of the cause, or of the former adjustment of the parts, the operator tries one thing after another and eventually either gives up in despair or by pure luck gets the motor running. In the former case a repairman's bill results in blaming the motor and gas engines in general, while in the latter case our friend flatters himself that he knows all about gas engines and thereafter poses as an expert with a fund of ready advice to every other user of a motor; and yet, should the same trouble arise again, he would be as much at a loss as before. This sort of trouble is far commoner with marine motors than with those in motor vehicles, for in a boat the engine is exposed and within easy reach, whereas in the vehicle it cannot be touched or meddled with while operating. It is mainly for this reason that vehicle motors appear to run more regularly and reliably than marine motors. Of course one now and then runs across an old, poorly designed, or worn-out engine that will run badly and cannot be depended upon, but in most cases a little adjustment here and there, a little lubrication, or some other small matter is all that is required. During a number of years' experience in handling and repairing gasolene engines, the author has yet to find a motor which could not be made to run—save in one or two cases where the engine was completely worn out and fit only for the junk heap.

Many books have been written on gas engines and their care and operation, but in the majority of cases these works are either too technical or are confined to one particular class of engines. Others describe and discuss oil, kerosene, and producer-gas engines, as well as those designed to operate on gasolene, and this is apt to be very confusing to the inexperienced, for while, strictly speaking, all these *are* gas engines, yet the individual peculiarities of different fuels require certain variations in design and operation in the motors and each should be made a separate study in itself. The purpose of the present work is to furnish all the necessary information regarding gasolene engines in simple language free from technical terms and as far as possible cover all variations, types, and classes of these motors and their various parts, accessories, and appliances. In order to illustrate the various types of engines and devices certain makes with distinctive characters have been used as examples, but the author wishes it clearly understood that such mention of a certain make of engine or accessory does not imply that it is the best or that it is recommended or endorsed by this work. Such mention merely indicates that the motor or appliance is typical of its class and is a well known and standard make.

As the number of gasolene motors on the market is steadily increasing and there are over ten thousand manufacturers of explosive engines in the United States to-day, it is practically impossible to mention more than a very limited portion of the various designs, innovations and improvements constantly being made in this industry. In all gasolene engines the principle is the same, and the care and operation identical, and the man who becomes thoroughly familiar with one engine will have no trouble in mastering any other.

As technical terms cannot be avoided under certain conditions, such as ordering new parts, making repairs, machine-shop work, etc., a glossary of such terms with an explanation of the meaning of each has been added to the work as well as an alphabetically arranged table of common troubles and their symptoms and remedies, features which the author believes will prove of great value to all owners, users, or operators of gasolene motors.

GASOLENE ENGINES

CHAPTER I

TYPES OF MOTORS. OPERATION AND EXPLANATION OF TWO-CYCLE AND FOUR-CYCLE MOTORS

ALL gas, gasolene, or oil motors, known collectively as Explosive Engines, may be roughly divided into two classes or types: the Two-cycle or Two-stroke engines and the Four-cycle or Four-stroke engines.*

While these two types are quite distinct in their construction and operation, yet the principle in each is the same. A charge of gas, gasolene, or oil vapor is drawn into the cylinder, is compressed therein by a piston, and while under compression is ignited by an electric spark or similar device. The force of the exploding gas drives down the piston which, acting upon a crank, transmits the power of the explosion to a revolving shaft and thence to the boat, vehicle, or machine requiring the power.

It will thus be seen that a gas of the highest explosive power, an ignition device that can be depended upon, and a cylinder that will not leak and lose compression are the most necessary essentials for the proper operation of a gas motor.

---

* The author is well aware that certain six-cycle motors have been built and used to some extent. In these engines the additional idle stroke is utilized to draw a charge of clean air into the cylinder in order to more perfectly scavenge the burnt gases. Such motors have not come into general use, however, and the ordinary operator is not likely to encounter an engine of this type. They are not considered of sufficient importance to be worthy of consideration in the *present work.*

The simplest form of gasolene engine is the Two-cycle in which the parts may be reduced to a minimum, only three moving parts being absolutely essential (Fig. 1).

In this figure the piston *A* is represented as being at the upward limit of its stroke with the space between the top of piston and top of cylinder *B* filled with a charge of compressed gas. At this position, or "Firing Stroke," an electric spark takes place at *C* and ignites the gas which, exploding, drives the piston *A* downward. At the point illustrated in Fig. 2 the opening *D* in the cylinder wall is uncovered by the piston, and the burning and practically exhausted gas rushes out through this opening and escapes. Almost at the same instant the opening *E* is uncovered and a fresh charge of gas—which has been contained in the base *F*—is forced up through the opening *G* to take the place of the exhausted charge (Fig. 3). The momentum of the moving fly-wheel and shaft now carries the piston on its upward course, closing the openings or "ports" *D* and *E* and at the same time drawing by suction a fresh charge of gas or gasolene vapor into the base through the opening *H* (Fig. 4). As the piston reaches the top of its stroke a spark again ignites the compressed charge, the piston is again forced down, and the operation repeated over and over again. In this motor it will readily be seen that an explosion or impulse takes place at every complete revolution of *the shaft or, in* other words, at every *two strokes* of the

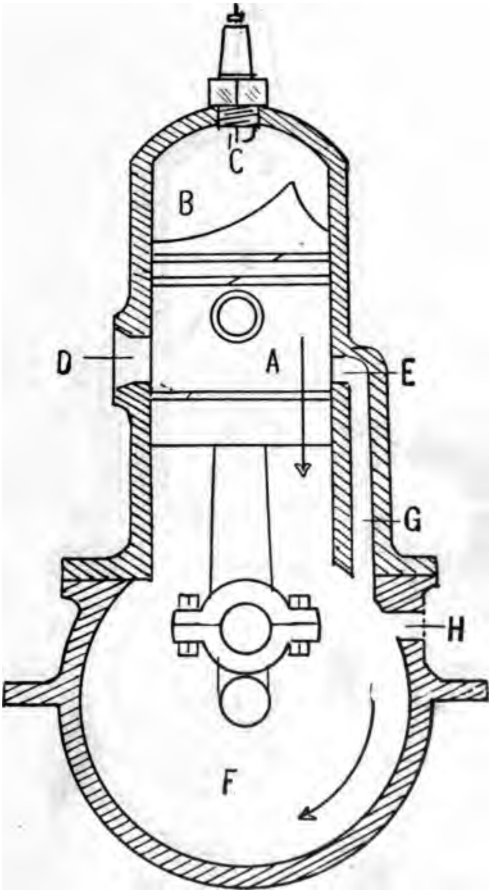


Fig. 1.—Operation of Two-cycle Engine

(See page 16)

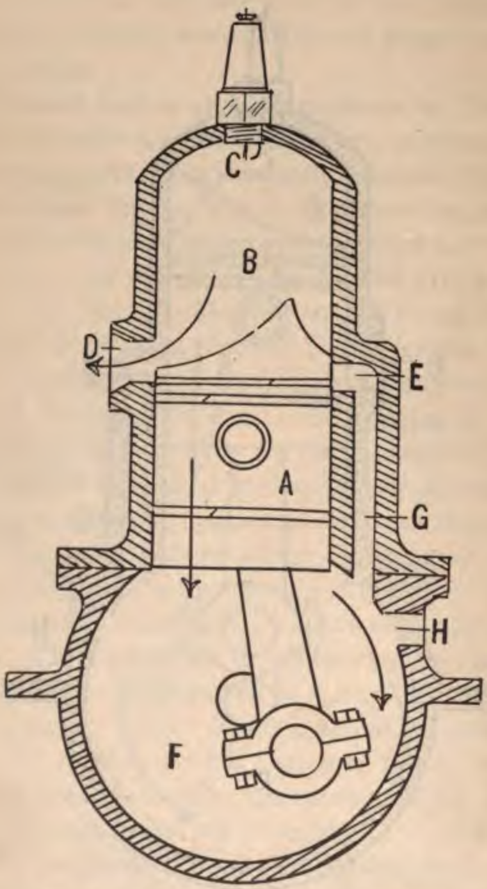


Fig. 2.—Operation of Two-cycle Engine

(See page 16)

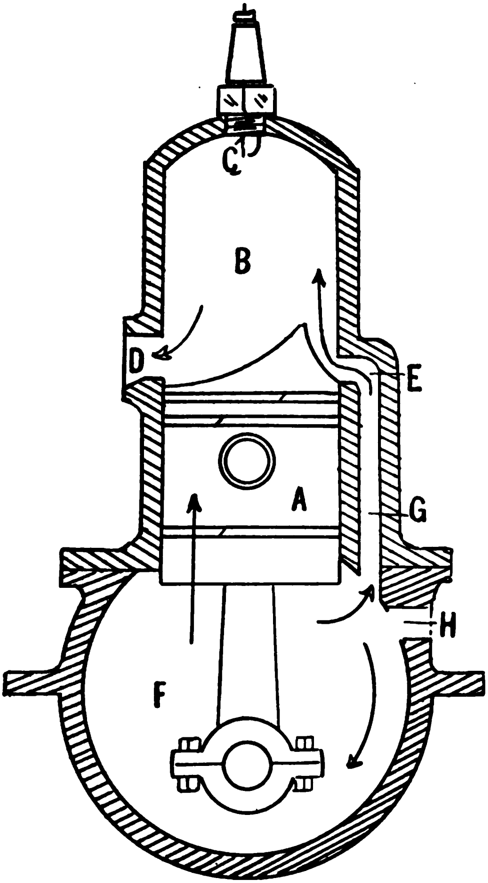


Fig. 3.—Operation of Two-cycle Engine

(See page 16)

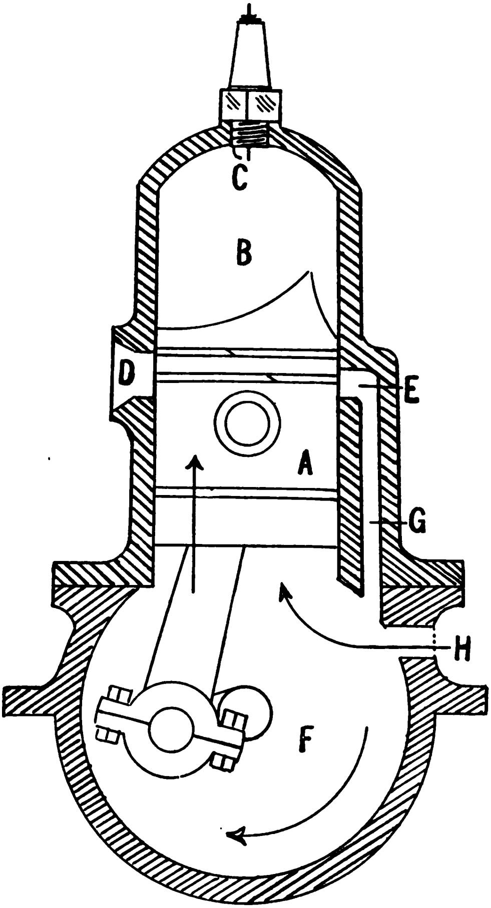


Fig. 4.—Operation of Two-cycle Engine

(See page 16)

piston. In order to first start a two-cycle motor in its operation a charge of gas or vapor must be drawn into the base and forced up to the top of the cylinder and compressed there. One complete revolution of the shaft is necessary to accomplish this, and this revolving a shaft by hand is commonly known as "cranking." Unless a motor is out of order or some adjustment is wrong one revolution only should suffice to start the engine, and if it fails to start then further cranking is merely a waste of time and strength until the fault is corrected. Indeed most motors when properly adjusted will start by merely rocking the fly-wheel back and forth and "throwing it up" against compression. In cold weather, however, motors will often start very hard and at such times "priming" should be resorted to. This matter will, however, be fully dealt with in the succeeding chapters.

In Figs. 5 to 8 a section of a four-cycle engine is illustrated. In this type of motor the parts are far more numerous and the operation more complicated. The motor is shown in Fig. 5 with the piston *P* at the top of stroke or "firing stroke," with a compressed charge ready to explode, and with both the valves *VI*, *VE* closed. The explosion taking place the piston is forced down as in the two-cycle motor already described, and the shaft is turned half a revolution. In its downward passage the exhaust valve *VE* is opened through the action of a cam *C* and gear *G* connected to the main shaft, and the motor then appears as illustrated in Fig. 6. The piston now commences its upward stroke, thus forcing the burnt gas out through the exhaust valve which remains open until the piston has reached its upward limit and has commenced to descend. At this point the exhaust valve closes and the intake valve *VI*

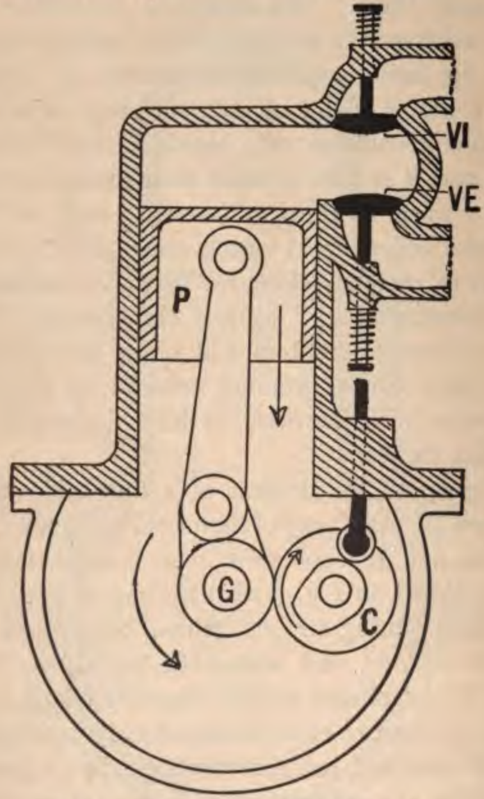


Fig. 5.—Operation of Four-cycle Engine

commences to open (Fig. 7). As the piston continues on its downward course its suction draws a charge of gas *in through VI* until the lowest point of the stroke is reached. The intake valve *VI* now closes, and as the exhaust valve *VE* still remains closed the upward stroke of the piston compresses the gas until again ignited by the spark (Fig. 8). The operation is then repeated over and over. By reference to the figures and the explanation it will be seen that in this form of motor an explosion

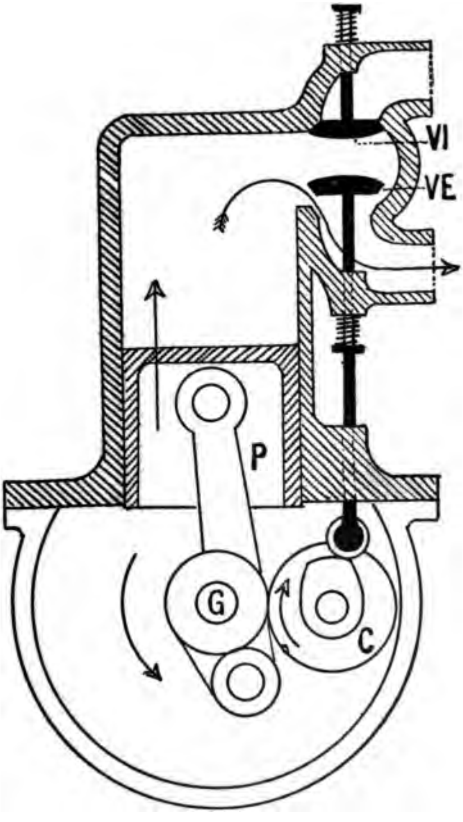


Fig. 6.—Operation of Four-cycle Engine

takes place at every *two revolutions* of the shaft or at every *four strokes of the piston.*

To the uninitiated it would appear that an engine receiving an explosive impulse on every two strokes would naturally be more powerful and would run more *steadily and* with less vibration than a motor receiving

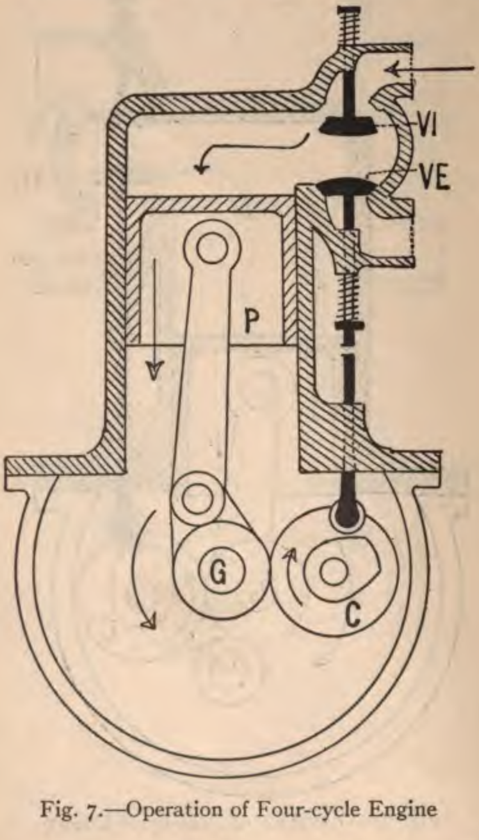


Fig. 7.—Operation of Four-cycle Engine

impulse only on every fourth stroke. In reality ere is but little difference in the power delivered by a o-cycle or a four-cycle engine; while as a rule steadi-

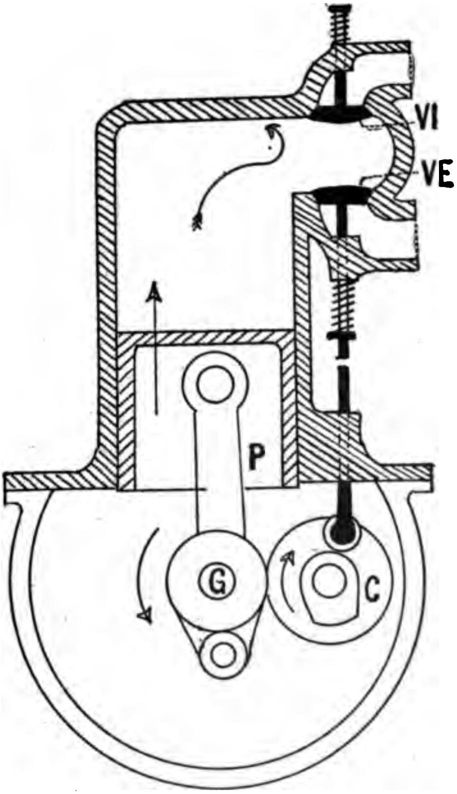


Fig. 8.—Operation of Four-cycle Engine

ss and reliability are in favor of the four-cycle motor. obably the four-cycle motor uses less fuel for the same wer *than a two*-cycle, but even this may be doubted in the case of many of the better classes of two-cycle engines. In the four-cycle type the burnt gases have a longer opportunity to escape, besides being mechanically forced out by the piston itself, and as a result the fresh charge of gas is purer and possesses better explosive properties and more power. Moreover, the idle stroke allows the cylinder more time to cool off while the valve action regulates the amount of charge taken into the cylinder more accurately than in the fixed opening, or port, of the two-cycle type. Each type of motor has its devotees who claim all the advantages for their own particular type, but it is doubtful if there is any great difference as far as actual utility is concerned. Both the two- and four-cycle types are used extensively in stationary work, but for light marine work the two-cycle type is the most used. For larger boats and where great power is desired the four-cycle engines predominate, while in automobiles and other motor vehicles four-cycle engines are almost universally used. This seems to be due to the greater perfection of the four-cycle engines rather than to their actual performance as compared with the two-cycle, for in a few makes of cars the latter are employed with very marked success. Although the two-cycle is so much simpler in construction and operation yet it is harder to design and build a really good two-cycle motor than a four-cycle, and usually it requires more care and more knowledge to regulate and adjust one correctly. This seeming paradox is explained by the fact that in a four-cycle motor the timing and regulating of the valves may be made to overcome *many* faults in the design or construction of the motor or its parts, whereas in the two-cycle motor every measurement must be within very exact limits in order for the motor to work at all. In adjusting motors the valves again cause the four-cycle to be the simpler, for a considerable difference in the amount of air or fuel, or even in more important matters, makes but slight difference in the apparent working of the motor, whereas in the two-cycle type a very slight difference in the proportions of the fuel causes a marked difference in the results obtained.

It has been claimed by many that the four-cycle is more flexible, or, in other words, can be varied in speed and power to a greater extent than the two-cycle motor, but I am inclined to doubt this. A properly designed and constructed two-cycle motor may be run satisfactorily at from one hundred to several thousand revolutions per minute without trouble, and many of the best four-cycle engines fail to run at all regularly when the speed is varied suddenly to any extent.

A very important point that is all too frequently overlooked by the owner or user of gasolene motors is the "human element." One man will get splendid results from a certain type or make of engine while another person will have continual trouble with it and condemn it outright. This peculiar adaptability, or "knack" as it may be called, of some operators with certain engines seems remarkable at first sight, but if carefully studied will usually prove to be due to the fact that the operator has thoroughly *learned* his engine. No two gasolene motors are exactly alike, and no two engines will run equally well with exactly the same treatment. This is more often due to surrounding conditions than to the motor itself, but nevertheless I have yet to see the engine that does not require some "humoring" and for this reason I strongly advise every purchaser or user of a gasolene motor to be sure that he has thoroughly mastered *his* motor and learned its ways before deciding that there is really anything wrong with the mechanism itself.

Before deciding on the type or make of motor suited to your particular requirements, study the matter carefully and study the advantages and disadvantages of each until thoroughly satisfied that you have selected the best motor for your purpose. There are many hundreds of motors made, and while practically every well-known and reliable firm turns out a good motor nowadays, yet some are better than others and each make and type possesses certain advantages that fit it for particular purposes or conditions.

Do not expect to get a first-class motor at an absurdly low price. It costs money to design and build a good engine, and while the large manufacturer, with special tools and machinery and every facility for turning out motors in large numbers, can make a much lower price than the man who makes each motor by hand and builds only a few at a time, yet if a motor is advertised at a *very* low figure, steer clear of it. As a rule the motors made by large firms at a reasonable price are far better than those made in small numbers at a high price, for in the former case the parts are interchangeable and new pieces may be purchased at a low figure and *will always fit*, whereas the small manufacturer seldom turns out parts that do not require considerable hand work before they can be made to fit an old motor. Many manufacturers depend on overrating their motors to increase sales. They will advertise a motor at almost double its actual power and sell it at the price others charge for the actual power advertised and thus appear to sell a motor at a very low price. Usually such motors are extremely high-speed, short-lived engines, or else the maker is deliberately trying to defraud you. There is no excuse for being swindled, however, for it is a simple matter to determine the horse-power of any motor. Bore and stroke and speed give the power, and while various motors may give more or less power according to design and workmanship, yet within certain limits the power may be readily determined.

The amount that the explosive gas is compressed before ignition also affects the power of the motor, as well as the proper adjustment of fuel, proper lubrication, and correct ignition. The power computed from these established factors is known as the *Indicated Horse-power*, but the whole of this power is never available. A large part is consumed in overcoming the friction in the motor itself, and the power remaining after this is overcome is called the *Delivered Horse-power*. The proportion of the Delivered Power to the Indicated Power is known as the *Mechanical Efficiency*, and is usually expressed in per cent. Thus if the Indicated Horse-power of an engine is 10 H.P. and the Delivered Power is 8 H.P., the Mechanical Efficiency will be 8/10 or 80 per cent, and the friction load (overcome in operating) will equal 10-8 or 2 H.P. While the pressure of the gas under compression varies considerably, according to the fuel used and design of engine, yet the pressures are so well known and the proper pressure so well established that an average of about 70 pounds per square inch may be counted on. With these factors known the following formulas may be depended upon to ascertain with reasonable accuracy the Delivered Horse-power of any gasolene motor.

For four-cycle motors: D.H.P. = Diam. of cylinder multiplied by itself, times the length of stroke, times the number of revolutions per minute, divided by 18,000. For example, the D.H.P. of a motor with a 3-in. bore, 3-in. stroke, running 1,000 revolutions per minute = $3 \times 3 \times 3 \times 1{,}000 = 27{,}000$, divided by 18,000 = 1½ D.H.P.

For the D.H.P. of a two-cycle motor proceed in the same manner, but divide by 13,500. Thus, a two-cycle motor with 3-in. bore, 3-in. stroke, and operating at 1,000 revolutions, would show $3 \times 3 \times 3 \times 1{,}000 = 27{,}000$, divided by 13,500, or 2 D.H.P.

Usually motors are tested by some form of pressure brake and the D.H.P. thus obtained is called *Brake Horse-power*. Such tests are reliable and accurate, but it must be borne in mind that the motors while undergoing these factory tests are operated under the most favorable conditions and by skilled engineers and mechanics; and the same motor that delivers 10 H.P. under a factory brake-test may not deliver over 6 H.P. when installed and operated by yourself.

It is far better to have too much power than too little, and a few horse-power more or less makes little difference in price. All other things considered you should choose *the motor having* the longest stroke and largest diameter and operating at a medium speed. High speed means short life, and large bore and short stroke mean high speed. Extreme long stroke and small bore, however, mean slow speed and additional weight, and an excess of either is undesirable.

With these remarks on the operation and principle of gasolene engines in general, we will now take up the matter of the various motors and their parts and accessories in detail.

CHAPTER II

TWO-CYCLE OR TWO-STROKE MOTORS

THE two-cycle motor already described and figured in the preceding chapter is known as the Two-port motor from the fact that there are but two openings, or ports, from the cylinder. Another form of two-cycle motor in common use is known as the Three-port motor (Fig. 9). The operation of this motor is essentially the same as the two-port type, but in addition to the two ports this motor has a third port or opening, *A*, which is closed by the piston acting as a sliding valve. On the downward stroke of this motor the third port is closed as shown in the figure, while the gas in the base is forced up to the top of the cylinder through the by-pass *B*. On the upward stroke the gas is sucked into the cylinder through the port *A*, as in the two-port type. The only advantage of this type of motor over the two-port is that no check valve is required in the inlet for fuel at *A*. It is usually a high-speed engine, and as a partial vacuum is created in the base on the upward or suction stroke and a considerable pressure must be maintained on the downward stroke, tight bearings and joints are essential and these, especially in a marine engine, are hard to retain for any length of time. Many of the more recent types of two-cycle engines are constructed so that either a two- or three-port system may be used as desired. A very *successful* motor of this design is the Gray Model "T," illustrated in Fig. 10. Almost any good three-port motor may, however, be transformed to a two-port

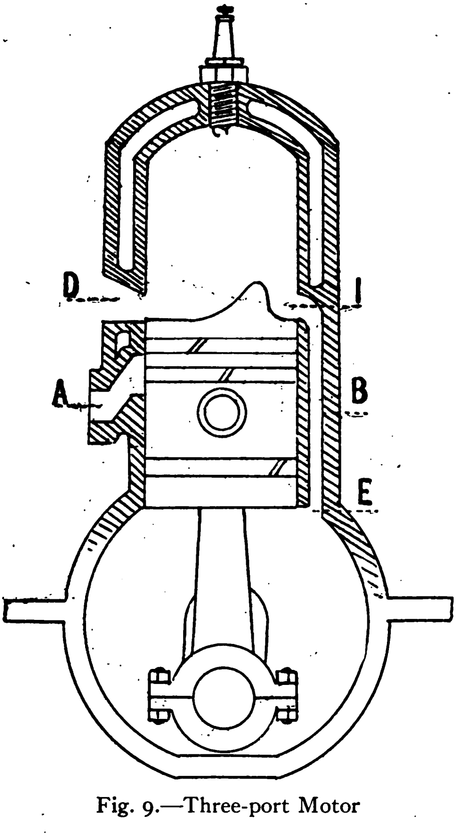


Fig. 9.—Three-port Motor

engine even after its efficiency as a three-port has expired.

Many of the best so-called two-port motors are in reality a sort of combination of the two- and three-port types. Such a motor is illustrated in Fig. 11. In this motor the inlet, or fuel, port, instead of being in the base as illustrated in Chapter I, is situated in the by-pass *B* midway between the base and the inlet to cylinder *C*.

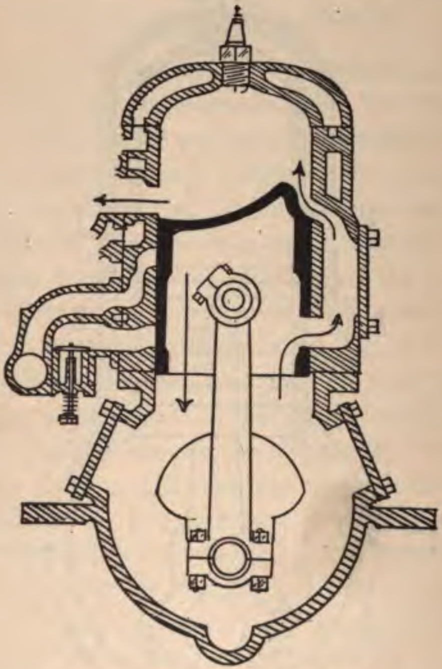


Fig. 10.—Gray Model "T" Motor

The operation of this type of motor is precisely the same as in the straight two-port, but it possesses many advantages over either the two- or three-port type. The suction created by the piston is greater than in either of the *other types, while* no great pressure is required in the base

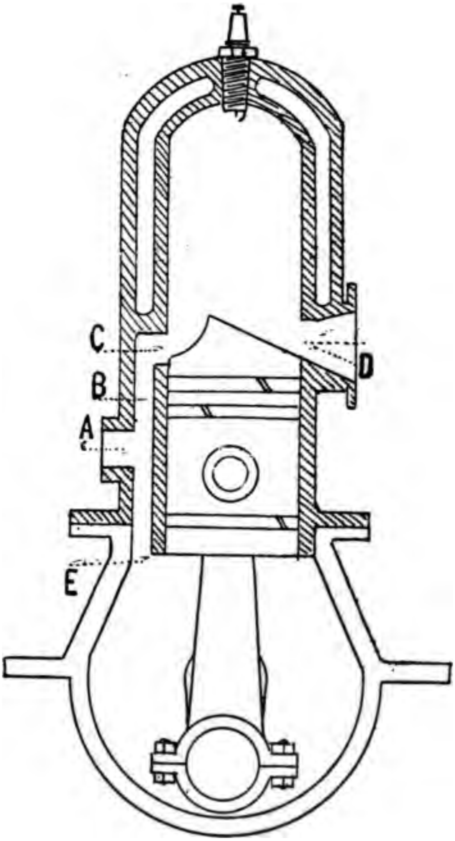


Fig. 11.—Two-three-port Motor

as in the three-port. The fuel-mixing device is elevated more than in the two-port, which is a distinct advantage in a boat, and the gas or vapor striking on the walls of the by-pass, instead of on the base of the engine, results in far better vaporization and consequently better combustion. The walls of the base are usually cold or nearly so and the mixture of gasolene and air tends to cool them off even more; whereas in the motor under consideration the walls of the by-pass are always warm while the motor is in operation and the mixture of gasolene and air striking this warm metal is immediately thoroughly vaporized. Many of the motors of this type have an opening in the base into which the fuel intake may be screwed. In such cases the operator may use his motor as a regular two-port or as a combination as desired. In many motors of this class very superior results are obtained by attaching an auxiliary air inlet in the base. This is closed when starting or running slowly, but when running at high speed is gradually opened until the best possible results are obtained. Such an auxiliary inlet is shown in Fig. 12 (*A*), and is known as an "Accelerator."

Two-cycle motors are also made which possess some of the best features of both the two- and three-port types. An example of this style of engine is the Grasser motor illustrated in Fig. 13. This motor has a vaporizer *A*, as well as an automatic air valve *B*, a third port *C*, and a transfer port *D*, which acts as the second port on a two-port motor. In operation the piston on its upward stroke draws a charge through the vaporizer *A* into the crank case *E*, until it reaches a point where the third

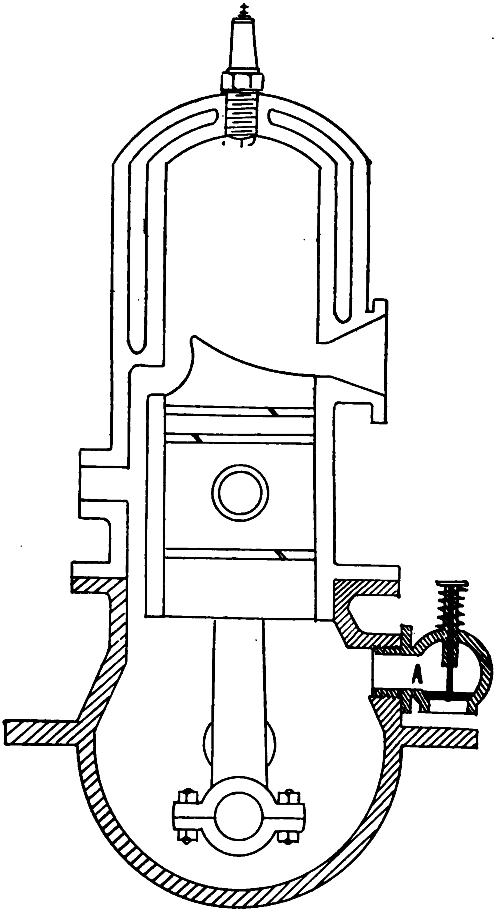


Fig. 12.—Two-three-port Motor with Accelerator

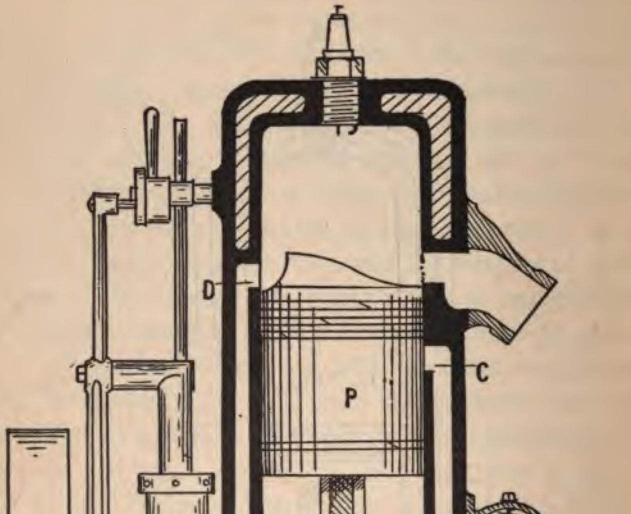


Fig. 13.—Grasser Motor

port *C* is uncovered. This permits the vacuum remaining to be displaced by air through the air valve *B*. As soon as the piston starts on its downward stroke the valve in *A* closes and the charge in the base is forced up through the transfer port *D* into the cylinder. This arrangement permits of a large, full charge of gas with consequently higher compression, more power, and freedom from crank-case explosions. In this motor the ports are placed in the forward and rear sides of the cylinders: by this method the piston and cylinders wear longer than if the ports were cut in the sides of the cylinder walls as the main thrust of a piston is sideways.

Still another type of two-cycle engine is so constructed as to admit the charge from the base through a port in the piston walls and hence through a by-pass and valve in the top of the cylinder. The Smalley engine is of this design, and is illustrated in Fig. 14. On the upward stroke of the piston a charge of gas is drawn through the fuel inlet *A* into the crank case *B*. When the piston starts downward this vapor is brought under compression until the piston reaches the lowest point of its stroke, whereupon the port *C* in the piston comes into line with the port *D* in the cylinder, thus allowing the compressed gas to rush up through the by-pass *E* and through the valve *F*, into the top of the cylinder. At the commencement of the upward stroke of the piston the valve *F* closes by the spring *G*, and the gas held in the top of the cylinder is compressed and ignited; the piston is driven down and the exhaust gas passes out through the opening *H*, as usual. This motor has several advantages, not the least of which is the cooling effect on the piston of the fresh charge of cool gas rushing through it at each stroke. The fresh charge coming directly in from the head of the cylinder also serves to drive out all

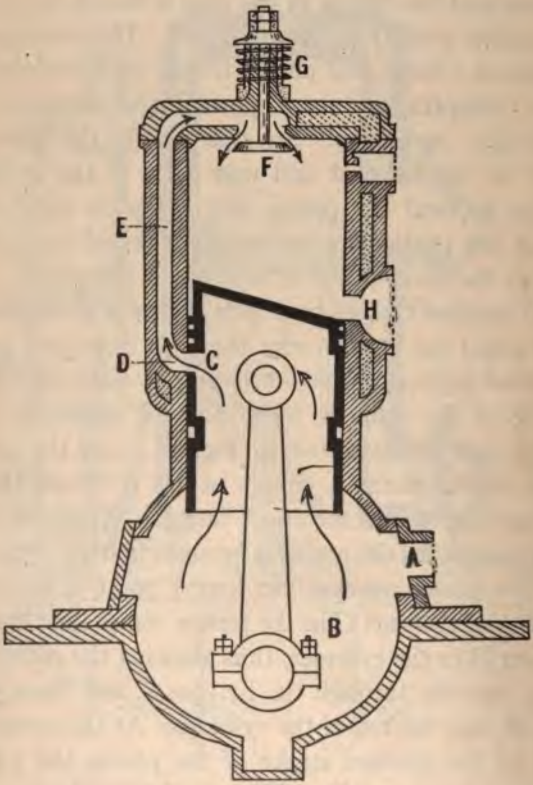


Fig. 14.—Smalley Motor

traces of burnt gas and results in a cleaner and better charge for firing. The only disadvantage in this engine *lies in the inlet* valve in the cylinder head. This valve in time will wear and cause loss of compression and will require regrinding as often as the valves of a four-cycle motor, and to the ordinary operator grinding of valves is a bugbear. Moreover, if the valve sticks, or the spring breaks, the motor is temporarily put out of service, and usually such accidents occur at the most inopportune and critical times; a similar engine with mechanically operated valve might be more satisfactory.

Several good motors of the two-cycle type are now constructed with an open base, or, in other words, without the closed crank case usually seen. This style of motor has many advantages over a closed-base engine. All the working parts of the crank, shaft, etc., are readily accessible for adjusting and oiling, and any danger of leakage and loss of compression in the base is obviated. An engine of this style of construction, made by the Powell Engine Co., is shown in Fig. 15. As will be seen by the diagram the piston *P* is hollow, and below it and above the base a compression plate *A* is placed through which the piston rod slides. Below the compression plate the piston rod is pivoted to the connecting rod *B*, at the cross-head *C*, which is a part of the same casting as the piston rod itself. On the upward stroke of the piston the gas is drawn into the space *D*, between the piston *P* and the compression plate *A*, through the inlet port *E*. On the downward stroke the gas is forced up through the by-pass *F*, to the port *G*, and thence to top of cylinder, exactly as in the ordinary two-port motor. After the explosion occurs the exhaust gases pass out through the port *H*. This motor possesses stronger compression than in a closed-base engine for forcing the charge into the

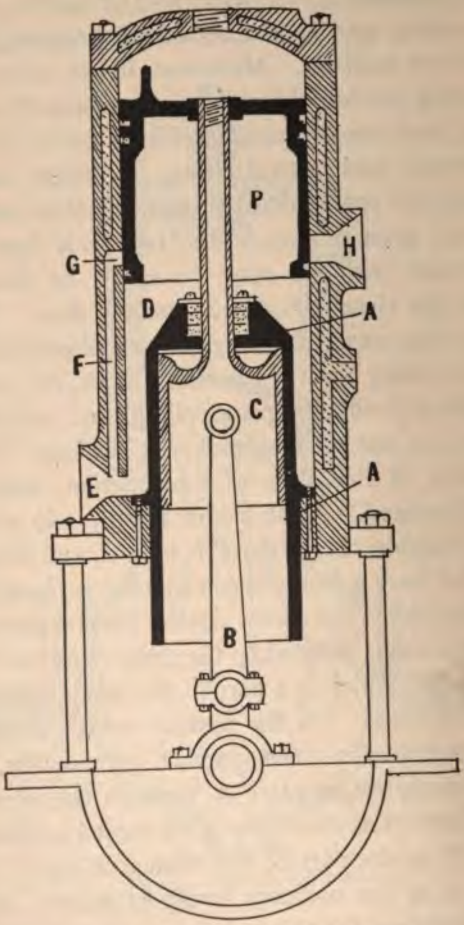


Fig. 15.—Powell Open-base Motor

cylinder, with a result that a quicker firing charge is obtained and also better scavenging of the burnt gases. The carburetor may be placed far lower than the lowest level of the cylinder, thus eliminating any danger of flooding, while the straight thrust of the piston rod and cross-head bearing do away with all side wear on the piston and cylinder walls. The cold charge of gas inside the piston also helps materially to cool the same, while the heat from the piston aids in better vaporization of the gas before its transfer to the firing chamber. The only objection to this type of motor is the additional height made necessary by the cross-head and connecting rod below the cylinder level. In stationary or marine use this is no serious objection, but for vehicle use it would necessitate a very high engine hood or small clearance beneath the shaft.

Several makers of two-port motors have also resorted to placing a throttle valve in the by-pass as shown in Fig. 16 (*T*), and while the speed and power of a motor so equipped may be controlled to some extent by this arrangement, yet as a rule I have found them rather unsatisfactory. A throttle on the fuel-mixing apparatus is far more reliable and easier to adjust. Some motors are also manufactured with a fourth, or air, port, and wonderful results are claimed for this type of motor. Undoubtedly it possesses many good points, but as a rule the fewer ports there are the more reliable the engine. To obtain the best results each port must be accurately designed and finished, and in a small engine the variation of a small fraction of an inch in the size of one or more ports will make a wonderful difference in the

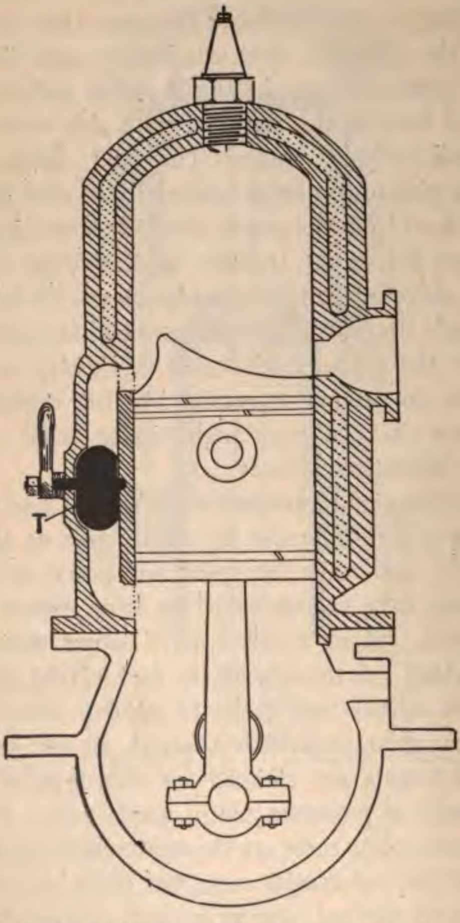


Fig. 16.—Motor with Throttle in By-pass

power and operation of the motor. Moreover, the first part of a motor that wears loose is generally the piston or the connecting rod between the piston and crank shaft. As a slight wear here causes the piston to have considerable play up and down in the cylinder, it will be easily seen that the variation in the amount of opening of each port during operation is considerable. With every port added this variation, due to looseness, increases the resulting variation of the amount of fuel admitted to the cylinder, and as the amount of play varies quite a little according to the load of the engine and its speed, it is very difficult to adjust a motor thus worn. In fact the results from a three- or four-port motor with a loose piston or connecting rod are almost as great as if the ports were rapidly but unevenly opened and closed by hand. Any one can thus readily understand why a strictly two-port motor will run more satisfactorily when old or badly worn than a three- or four-port engine.

Probably the most reliable and efficient two-cycle motor yet produced is the Elmore, which is used in the well-known Elmore automobiles. This motor, which is illustrated in Fig. 17, is entirely distinct from most other two-cycle motors and in its construction and operation it overcomes most of the objectionable features of the two-cycle engine. The figure is purely diagrammatic and represents a section of one of the four cylinders and a portion of the base cut away.

The piston of the Elmore motor differs materially from that of other motors, inasmuch as the lower half or base is much greater in diameter than the piston proper (Fig.

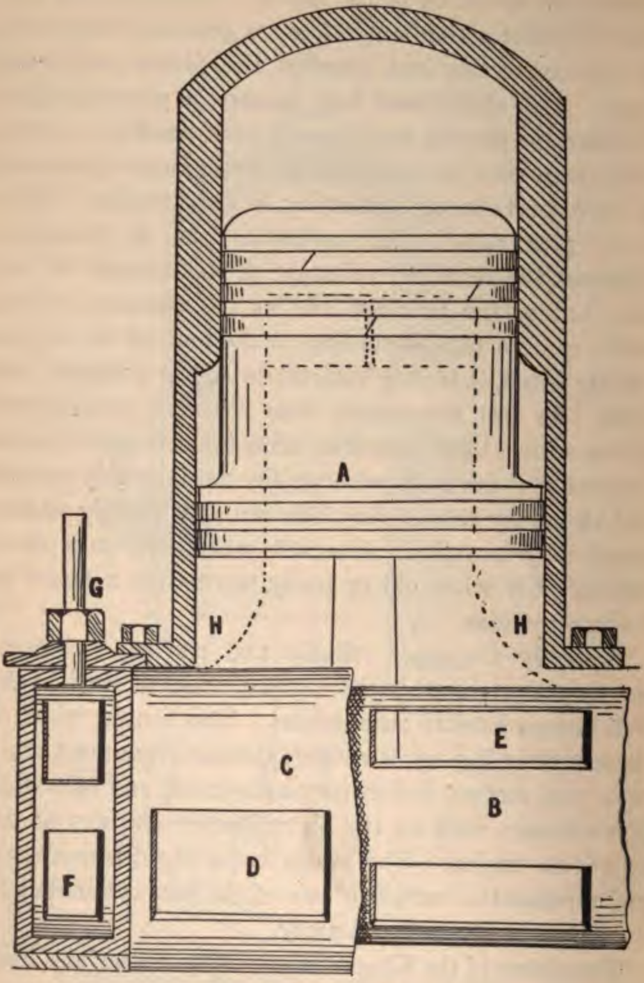


Fig. 17.—Elmore Motor

17 *A*). The up-and-down motion of this large half of the piston acts as a gas pump and alternately draws in gas to fill the lower half of cylinder or base, *H*, and forces it out under considerable pressure. When the slightly compressed gas is driven out of the base it does not at once find its way up through a by-pass and port into the same cylinder as in the ordinary motor, but, through the agency of a gas "distributor," is introduced to the firing chamber of another cylinder. This "distributor," which is the essential portion of the Elmore motor, consists of a revolving cylinder *B* almost surrounded by another cylinder *C*. The chambers thus formed are provided with long ports running lengthwise; those of one chamber opening on one side of the distributor *D* and those of the other chamber opening on the opposite side *E*. In operation the distributor is revolved within its casing by a silent driving chain from the crank shaft, each end being supported by spindles and ball bearings.

In action each lower half of a cylinder receives gas drawn through the outer chamber of the distributor. This gas under low compression is then returned to the inner chamber of the distributor, from which it is led into the firing chamber of the cylinder whose piston is just commencing the ascending or compression stroke. Compression and explosion then follow exactly as in any other engine, and the operation is repeated in each cylinder in proper order, thus giving four explosions or impulses to the crank shaft with cranks set at 90-degree angles.

It must be borne in mind that the chambers of the distributor do not extend through its entire length. The inner chamber *B* is divided at its centre, thus dividing the distributor into two equal parts. These two parts are connected by means of a by-pass *F* which is opened or closed by the operation of the throttle *G*. Until the throttle is opened half-way the two halves of the distributor operate independently, with the result that the cylinders work in pairs. When the throttle is half-opened the central control automatically opens and the power of the motor is then at once increased through all four cylinders operating alternately.

This Elmore motor, although apparently complicated, is in reality far simpler and has less parts than the ordinary four-cycle engine. Although advertised as a "valveless" motor, it is not strictly a valveless engine, for the "distributor" is actually a sort of rotary valve. The motor may therefore be considered a rotary-valve two-cycle motor. There is no doubt of the high efficiency of this engine, and its design and construction mark a great advance in two-cycle engines. The loss of base compression, unequal distribution of gas, loss or waste of fuel, and various other defects of the ordinary two-cycle engine are entirely overcome in the Elmore, and its flexibility, power, reliability, and economy of fuel are fully equal to many, if not all, six-cylinder, four-cycle motors of equal rating. In comparison with four-cylinder, four-cycle motors of the ordinary type, the Elmore is far ahead. The trouble and difficulties experienced with poppet-valve, four-cycle motors is absent in the present motor, but the revolving distributor, chains, numerous rotating ports of the distributor, and the various other parts must be perfectly timed and free from any lost motion or undue wear to work satisfactorily. These various parts of the rotating mechanism render the motor far more complicated than the regular two-cycle machine and it is therefore doubtful if this type of motor is so well adapted to the ordinary needs of the gasolene-engine user as either the regular two- or four-cycle engine. As a vehicle motor it is most efficient, and for this purpose—for which it was designed—the rotary distributor is no objection. For small boat or stationary use, however, the simplest engine is the best, and motors for this purpose should be selected which can be readily repaired, adjusted, or taken down and cleaned by inexperienced hands.

Two-cycle motors, as well as those of the four-cycle type, are usually made in either one, two, three, four, or six cylinders. The operation of a multiple-cylinder, two-cycle engine is practically the same as in a single-cylinder, but certain parts are slightly different in construction and design. In a two-cylinder motor the piston of one cylinder is on the downward stroke while that of the other is on the upward stroke, or, in other words, the cranks of the shaft are set opposite one another or at an angle of 180 degrees (Fig. 18). In a three-cylinder motor the cranks are set at 120 degrees (Fig. 19), while in a four-cylinder motor the cranks may be set at 90 degrees (Fig. 20 *A*), or at 180 degrees as shown in Fig. 20 *B*, *C*.

Three-cylinder motors have some advantages over the two- or four-cylinder machines, but they are more difficult to time correctly and either two- or four-cylinder engines are more widely used.

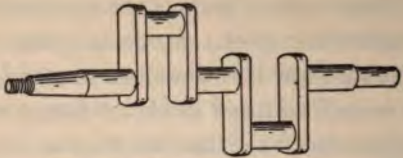


Fig. 18.—Two-throw Crank

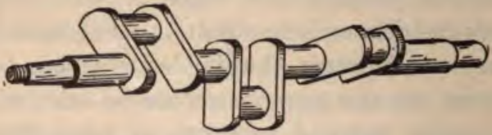


Fig. 19.—Three-throw Crank

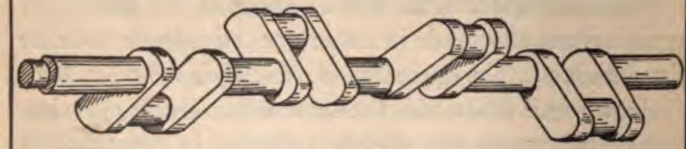


Fig. 20A.

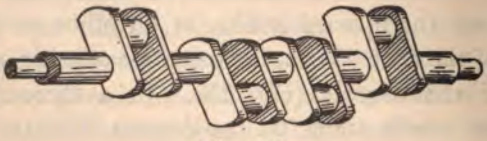


Fig. 20B.

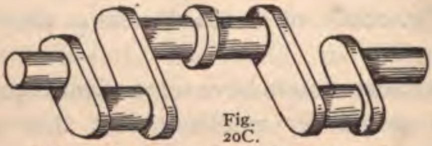


Fig. 20C.

Fig. 20A–B–C.—Four-throw Crank

A multiple-cylinder motor will not deliver as much power in proportion as the same number of cylinders in separate motors, but on the other hand they run far more steadily and with less vibration than the single-cylinder engine. Moreover, they are easier to control and if one or more cylinders fail to work the engine will usually operate on the remainder, and while in action the faulty cylinders may be adjusted until all are in running order. Few multiple-cylinder engines will carry a full load when any of the cylinders fail; and as a rule such engines, as well as all but the smaller single-cylinder motors, should be provided with a clutch, or gear, so that they can be run free from a load when so desired.

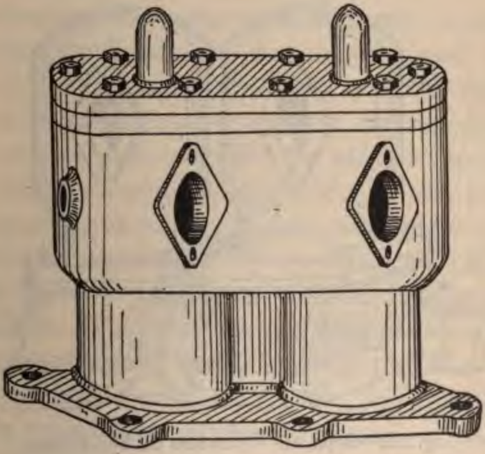


Fig. 21.—Cylinders *en bloc*

Multiple-cylinder motors have numerous disadvantages, especially for the person unfamiliar with explosive engines or other machinery; their parts are far more numerous than in the single-cylinder motor; they are harder to "crank" or turn over, and if any adjustment or regulation is wrong it is far more difficult to locate the trouble. In case of a serious trouble or breakage a multiple-cylinder motor is more difficult to take down than an engine of one cylinder, and in many makes the entire machine must be taken apart in order to reach a break or injury in any one of the cylinders or its parts. Multiple-cylinder engines of the two-cycle type are made either "en bloc" with the several cylinders in one casting (Fig. 21), or are built up of several separate cylinders bolted to a single bed plate or base (Fig. 22). Each of these systems has its advantages, for while the *solid casting* results in a more compact and stronger

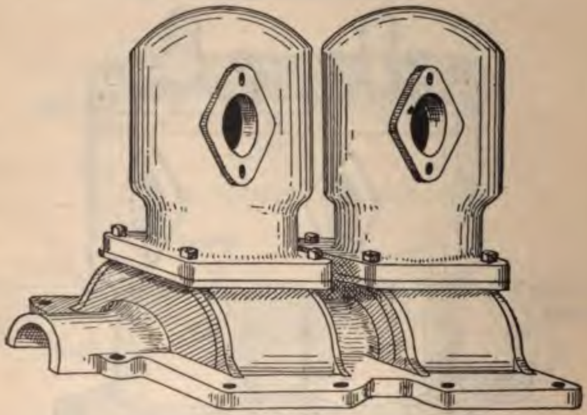


Fig. 22.—Separate Cylinders on Solid Base

engine, the built-up motor is easier to take apart and repair.

For vehicle use and marine work, where considerable power is required, multiple-cylinder motors are almost universally used, but for stationary work, except where great power is necessary, single-cylinder engines give satisfactory results.

In estimating the power of motors with several cylinders the formulæ already given may be used, but the square of the bore times the length of stroke should be multiplied by the number of cylinders before multiplying by the number of revolutions; for example, to find the D.H.P. of a three-cylinder motor of 4-in. bore and 4-in. stroke operating at 500 revolutions per minute: $4 \times 4 \times 4 \times 3 \times 500 = 96{,}000$ divided by $13{,}500 = 7\frac{1}{2}$ D.H.P. It must be borne in mind that these figures are merely approximate. The *only* method for determining the *exact* power of an engine is by actual test, but the use of formulæ helps a great deal in selecting a motor, as it gives the prospective purchaser, or user, a reasonable idea of the power he may expect a motor to deliver under normal conditions when operating at the number of revolutions indicated.

CHAPTER III

FOUR-CYCLE MOTORS

To a person familiar with two-cycle motors the four-cycle engines appear extremely complicated at first. With the number of moving parts reduced to the minimum in the former, their operation and care seem easy and their mechanical construction and principle very simple. In the four-cycle motors the parts are greatly increased in number while the moving push rods, cams, gears, and springs make the engine appear a most bewildering piece of mechanism. This apparent complication has done much to prevent the adoption of four-cycle motors for light marine and stationary work, for many people seem to think a skilled engineer is necessary to operate one of these motors. In reality a four-cycle engine is very simple if we study it properly, and its care and operation are almost, if not quite, as easy as those of a two-cycle.

In fact, a good four-cycle engine requires less personal attention and can be handled more readily when at a distance or out of reach than a two-cycle, as is evident from the facility with which automobile motors are started, stopped, and handled from the driver's seat while the motor is completely out of sight and reach. Four-cycle motors are made in any number of cylinders from one to eight or more; but as the mechanism and operation are identical in each cylinder, a single-cylinder machine once understood will render any multiple-cylinder motor intelligible.

Four-cycle motors, like the two-cycle engines, consist of a cylinder, piston, base or crank case, connecting rod, shaft, and fly-wheel. In addition to these common parts it also has a number of other moving pieces whose function is to operate the valves. These parts are known collectively as the *valve mechanism*, and as they seldom require attention their complicity need cause no worry. As in two-cycle motors, there are various styles and variations in four-cycle types. The commonest form in use is known as the *poppet-valve* or *mushroom-valve* engine. In this motor the valves for the inlet of the vapor charge and for the outlet of the exhaust are mushroom-shaped, consisting of a rounded or flat disk-like head attached to a cylindrical shaft or spindle called the *valve-stem* (Fig. 23). Nine-tenths of the four-cycle motors in use to-day employ this style of valves, and their variation consists mainly in the method employed to operate the valves or in the location of the valves in the cylinder casting. As the valves operate but once for each complete revolution of the crank, it is necessary to attach the valve mechanism to some form of gear with a ratio of two to one, or, in other words, to so reduce the speed of the shaft operating the valves that it makes

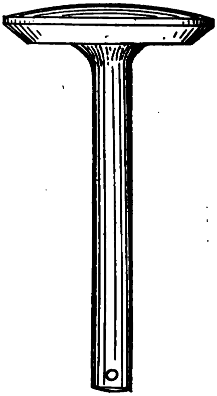


Fig. 23.—Tappet Valve

but one revolution to every two revolutions of the motor shaft.

This may be accomplished by either cog-wheels, worm-gear, or sprocket-wheels and chain. Practically every form of gear is used by the various makers of four-cycle engines, but the worm- or screw-gear, or the gear-wheels with slanting teeth known as the "helical gear," are the most satisfactory and are now generally used.

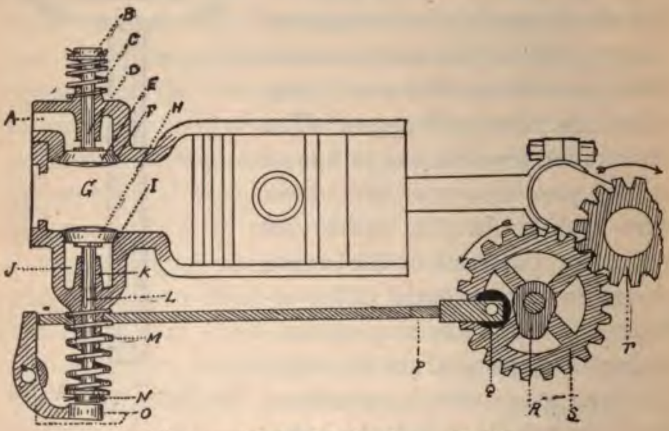
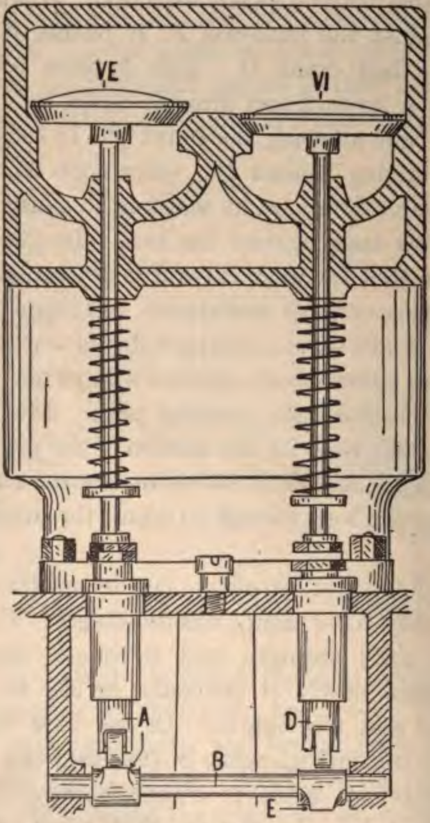


Fig. 24.—Valve Mechanism. Cadillac

In the earlier designs, as well as in many modern motors, plain cog-wheels or *spur-gears* are used. These work very well, but wear faster and are far more noisy than the screw, or helical, forms. In Fig. 24 the valve mechanism of a motor using the spur-gear is shown. In the illustration, *T* represents the cog-wheel attached to the engine shaft, and *S* a gear of twice the size of *T*, attached *to a separate* shaft. Keyed to this shaft is a cam *R*, which turns against the roller *Q* pivoted in the push-rod *P*. As the engine shaft revolves in the direction indicated by the arrows, the wheel *S* revolves at half the speed and in the opposite direction. When the cam *R* runs against the push-rod *P*, it pushes it outward against the bell crank *O*. This in turn presses the valve stem *L* upward and lifts the outlet valve *H* from its seat *I*, thus allowing the burnt gas to escape. The spring *M*, acting against the valve foot *N*, serves to bring the valve firmly on its seat and to cause the push-rod to follow back against the cam. In this motor it will be seen that the inlet valve *E* is not connected with any valve gear or other mechanism, but is provided with a spring *C*, which serves to keep it firmly seated. This is known as an *automatically operated valve*, while the outlet valve is a *mechanically operated valve*. Many motors are built in this way, for the suction of the piston on the intake stroke is sufficient to act on the inlet valve and cause it to open long enough to admit the proper charge of gas.

Although several excellent motors utilize this system, yet they have many disadvantages. The springs soon lose their strength and liveliness, causing the valve to open slowly or unevenly, or else to open too readily and seat too lightly. In one case the charge admitted is insufficient, while in the other case the compressed gases are liable to escape backward into the inlet and cause loss of power and back-firing. Moreover, in case of a leakage around the piston, or in the firing chamber, the suction of the piston may prove unequal to the *task of opening* the inlet valve far enough or long enough to admit a full charge. It is far better to operate both inlet and outlet valves by mechanical means as illustrated in Fig. 25, in which the exhaust valve is



ig. 25.—Mechanically operated Valves

actuated by the push-rod and cam *A*, attached to the *am-shaft B,* and the inlet valve VI is also operated by another push-rod *D* through the cam *E*, on the same shaft with the exhaust-cam, but set at an angle with it. By this method there is no chance of the inlet valve sticking on its seat or failing to seat and if the cams and gears are set properly a uniform and correct charge will always be admitted to the cylinder at exactly the right time. This is a very common and widely used type of four-cycle motor. The exterior form is shown in Fig. 26. It is known as the *T-head* or *L-head* type from the shape of the cylinder and valve chamber. More recent still is the *valve-in-head* type in which the two valves are located in the head of the cylinder instead of in an offset, or separate, chamber. This type (Fig. 27) has many advantages over the T-head type, and is now generally acknowledged to be far more effective and

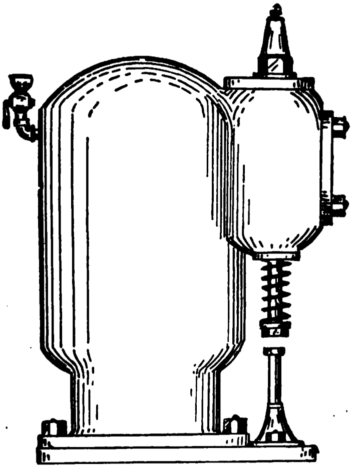


Fig. 26.—"L"-head Cylinder

economical. The two valves being set in the cylinder head allows the interior to be machined smooth and free from corners, or pockets, where burnt gas might accumulate. The incoming charge also serves to thoroughly fill the chamber and the outgoing exhausted gas is more thoroughly discharged. The cylinder head and valve seats, as well as the piston head, are also greatly cooled by the fresh charges of gas, while the arrangement of the valves allows the greatest cubical capacity of the cylinder with the least area of surface. Most of the various makes of poppet-valve motors vary principally in the valve mechanism, style of gear, and other minor details; but motors with rotary and sliding valves have now come into use and in their perfected state give results equal to, or even better than, the best poppet-*valve engines.*

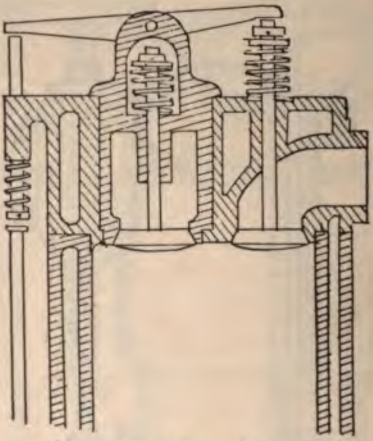


Fig. 27.—Valves in Head

The *Knight Sleeve Valve* motor is a comparatively recent invention, but has won its way rapidly to popularity and success by its remarkable performances in several well-known makes of automobiles. In this engine, which is shown in Fig. 28, the piston is surrounded by two cylindrical sleeves, or tubes, one within the other and both between the piston itself and the walls of the cylinder proper. The diagram (Fig. 28) shows a section cut away to show the piston *P*, the inner sleeve *S*, and the outer sleeve *O*, while *C* represents the cylinder walls. The two sleeves are connected with connecting rods and eccentrics to the gear shaft, as illustrated in Fig. 29, in which *P* represents the piston, *S* the inner sleeve, *O* the outer sleeve, *C* the cylinder, *A* and *B* the connecting rods to the two sleeves, and *D* the eccentric attached to the gear shaft *E*. The gear is in the form of a sprocket-wheel *E* connected with the main shaft by a roller chain *F*. In the sleeves are openings, or ports, *G*, *H*, which are alternately brought opposite the exhaust and inlet ports in the cylinder, *I*, *J*. In operation the sleeve *O*, sliding past the sleeve *S*, brings the ports *G*, *H* opposite one another as well as in line with the inlet port *I*. This occurs on the downward stroke of the piston and the charge of gas is thus drawn into the cylinder as in Fig. 30. On the upward or compression stroke, the sleeves move to the position shown in Fig. 31, in which the ports *G*, *H*, *I*, *J* are all out of line and thus closed against the escape of gas from the cylinder. The charge is compressed and fired on the limit of this upward stroke as usual and the piston driven downward. Near its lower limit two of the ports are again brought opposite the

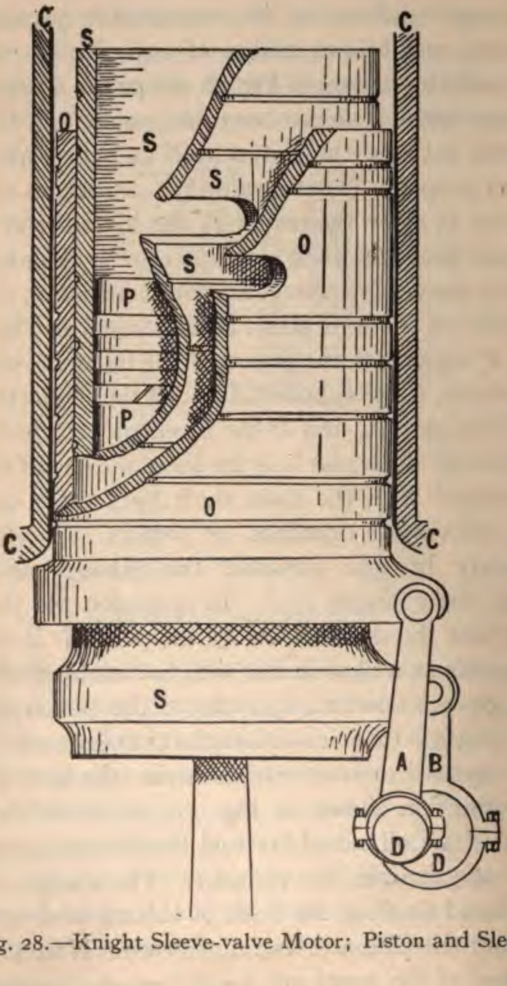


Fig. 28.—Knight Sleeve-valve Motor; Piston and Sleeves

outlet port and the burnt gas is forced out through the exhaust on the upward return stroke as in Fig. 32. This Knight type of motor is practically noiseless in operation, has little wear, and obviates all trouble with badly fitting or worn valves or weak springs. It also provides an ample and uniformly sized opening for both intake and exhaust of gases, and tests appear to prove that it actually improves in efficiency with age and use. The sliding sleeves must of course create quite an appreciable amount of friction, although it is doubtful if this is much

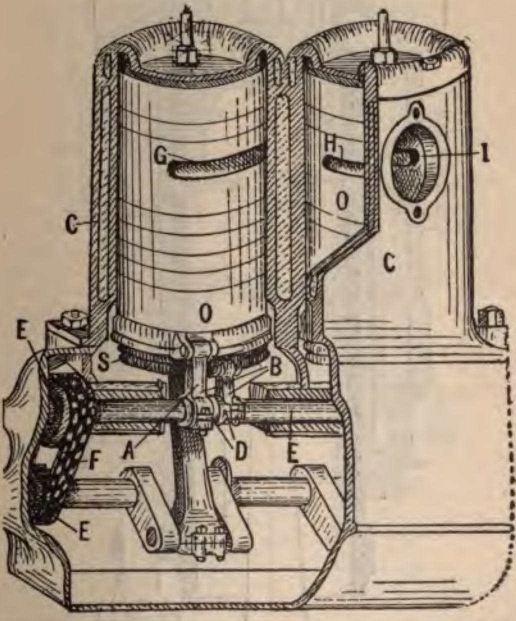


Fig. 29.—Knight Sleeve-valve Motor; General View

greater than the combined friction on the various cams, push-rods, valve stems, springs, and other parts of the poppet-valve motor. Lubrication is very essential to this motor, for if allowed to run dry, or to overheat, the friction on the sleeves becomes enormous and severe cutting and extreme wear soon result.

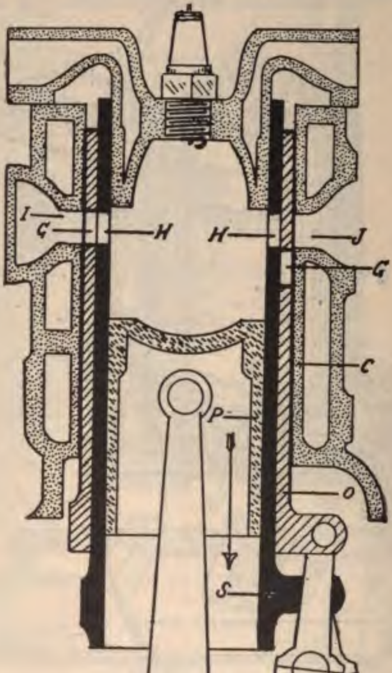


Fig. 30.—Knight Sleeve-valve Motor; Section to show Operation

Rotary-valve motors are now being made which work *excellently;* and the Reynolds motor, illustrated in

Fig. 33, has proven a most practical and reliable engine of this type. The illustration represents a view of the upper portion of the cylinders with the rotary valves *A* in place in cylinders *II*, *III*, and *IV*, and removed from

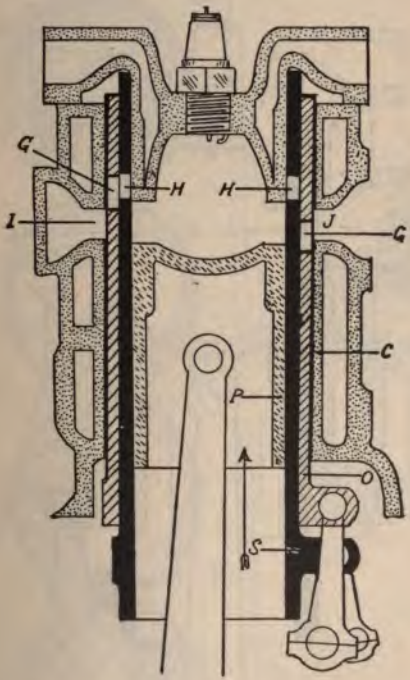


Fig. 31.—Knight Sleeve-valve Motor; Section to show Operation

cylinder *I*. The valves consist of circular disks *A*, *A*, revolving in recesses machined in the cylinder heads *R*, *R*, and are provided with openings *B*, which correspond in shape with openings in the cylinder heads, *C*, *D*. The cylinder (position *IV*). On the upward or compression stroke the valve continues in its rotation and covers the inlet port *C* and permits proper compression of the charge which is fired in the usual manner (position *II*). After the explosion the piston on its downward stroke revolves the shaft with its connecting gears and thus rotates the valves until the opening *B* uncovers the exhaust port *D*, through which the burnt gases are forced by the returning piston (position *III*). This motor is too new to judge of its ultimate future or general adoption, but it possesses many advantages over either the poppet-valve or sleeve-valve types, and where it has been used it has given most highly satisfactory results. The exhaust opening being a trifle larger than the inlet, allows a full and perfect scavenging of the burnt gas, while the uniform and accurate opening of the inlet and exhaust ports is fully equal to the same results obtained in the Knight motor. The valves being of bronze form their own bearing surface on the iron of the cylinders, while the constant rotary motion and the fact that they are always firmly seated prevent the formation of carbon deposits. Of course there is some wear of the valves against their seats, but adjustment for taking up this small amount of abrasion is provided.

There is comparatively little friction and the valves are provided with ball bearings at the upper end of the stems, while the action of the spiral or helical gears is positive, accurate, and practically noiseless. The shaft gear, vertical valve driving rod, and valve gears are all enclosed, giving the motor a very neat and clean appearance, and yet all are readily accessible. Although heretofore used principally as a marine engine, yet there is no reason why the rotary-valve motor should not give equally good results in stationary or vehicle use, and automobiles are now being equipped with this motor which will doubtless prove most successful.

Another rotary-valve engine which has recently appeared on the market is the Russell motor manufactured by The Silent Valve Co. of America. In this engine the rotating valves are conical in form and through a special arrangement of driving yokes and springs the valves automatically adjust themselves for

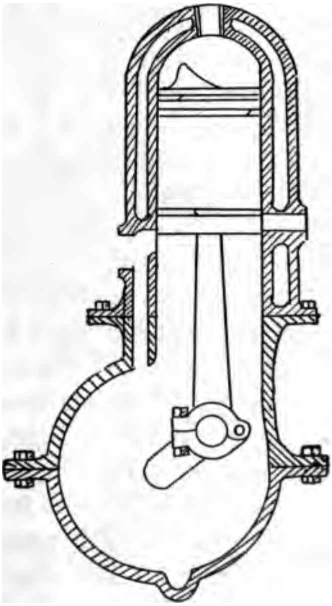


Fig. 34.—Offset Cylinder Motor

wear or expansion. Doubtless many other designs of rotary- and slide-valve motors will soon appear, for the present tendency of design is to improve upon the old poppet-valve mechanism. For general use, however, it is doubtful if this type of valve can be greatly improved upon.

Four-cycle motors vary considerably in design and arrangement of parts with different makers. These motors, as well as those of the two-cycle type, are often made with the cylinders offset (Fig. 34), a system which is supposed to overcome the tendency to a dead centre and which is used to a considerable extent on vehicle motors but has never become general on marine or stationary engines, but is a special feature of the well-known Ferro engines. Motors with the cylinders horizontal and opposed or opposite are also widely used, and this arrangement has many advantages over the vertical-cylinder motors and has been adopted by many makers of marine, vehicle, and stationary engines. These motors are very compact, light, and powerful, and the balanced method of construction gives a minimum vibration owing to the impulse from the opposite pistons overcoming the jar and rotary tendency of ordinary motors (Fig. 35). For small vehicles such motors are excellent and in many classes of boats they are far more convenient than the regular vertical engines. Their operation, as well as that of certain "V-shaped" models, is practically the same as in the ordinary four-cycle motor, but in the opposed-cylinder type the two cylinders may be adjusted so that the explosion in the *two cylinders* occurs alternately, thus giving an impulse for every revolution as in a two-cycle motor. Multiple-cylinder, four-cycle motors are made in from two to six or more cylinders, but in the four-cylinder machine the cranks are set at an angle of 180 degrees and are commonly constructed with the two central cranks close together without a central bearing, or with a very small

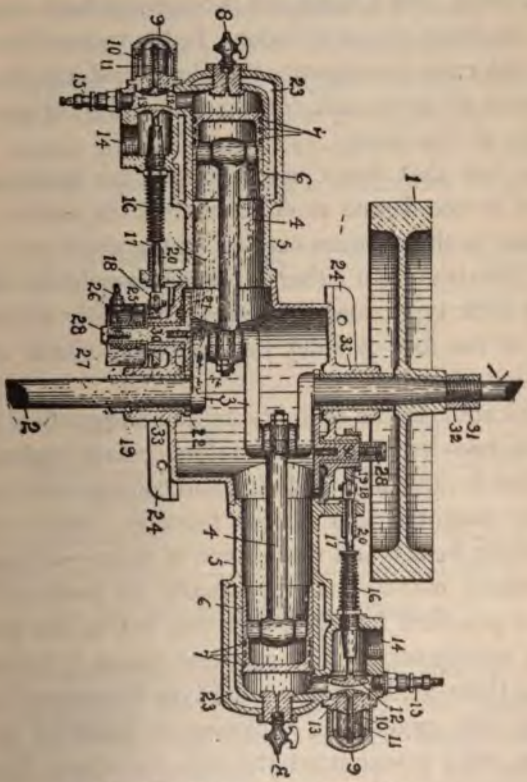


Fig. 35.—Opposed Cylinder Motor

one, thus allowing the two middle cylinders to be more closely placed and saving considerable space (Fig. 20, *B*, *C*). This method is possible in a four-cycle motor as the crank case is open and is one continuous chamber from the front to rear cylinder. In the two-cycle motors the crank cases are separate and closed and it is therefore necessary to have each crank separated by a gas-tight bearing on the shaft.

The fact that four-cycle, four-cylinder motors have cranks at 180-degree angles renders such motors more irregular in the pressure exerted on the shaft and causes more vibration than either three- or six-cylinder motors of the same type; and the latter are rapidly taking the place of the four-cylinder engines where silent, steady operation is desired.

In addition to the ordinary types and practical forms of both two- and four-cycle motors, many original and remarkable variations in design and construction are frequently patented and offered for sale. Such designs are mainly freaks, and while some of them—such as the true rotary motor—may eventually be perfected and become practical for every-day use, yet at the present time a satisfactory rotary gasolene engine is unknown. Among these freak designs is the type illustrated in Fig. 36. In this engine the explosion is balanced by the motion being transmitted through the levers *D*, *F* to the cranks *G*, while the explosion occurs between the two pistons *H*, *H*, thus driving the levers *D*, *D* by the connecting rods *E*, *E*. While this motor actually works, yet it has no advantage over any other opposed-cylinder motor and has innumerable disadvantages, not the least of which is the extra weight of the various moving parts. All these levers, cranks, etc., also add a great deal to the friction, while the loss of power through worn bearings and lost motion more than offsets any possible advantages the design may possess. Numerous motors have been designed in which an impulse occurs alternately at opposite ends of a piston, thus giving an explosion for every stroke of the piston. Motors of this design are expensive to construct and the difficulties in properly cooling and lubricating the connecting and piston rods are very great. In very large sizes such engines are in use, however, and give excellent satisfaction. A detailed description is not necessary, as the operation of these motors is practically identical with single-acting engines, although in some designs the mixture of fuel and air is forced into the compression chamber by the action of a pump cylinder operated by an eccentric or cam.

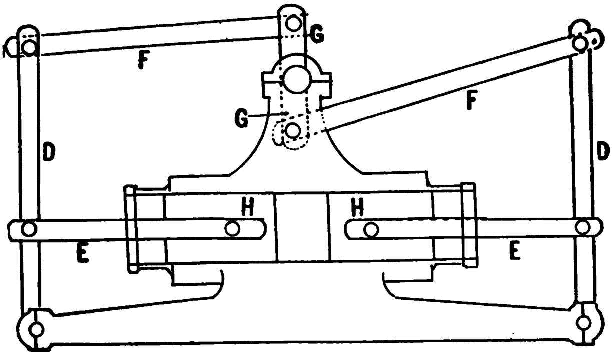


Fig. 36.—Freak "Balanced" Motor

Both two-cycle and four-cycle motors are frequently made in horizontal form (see Fig. 37) for stationary use. For such purposes a horizontal engine is often superior to a vertical machine, as it gives a wider, longer, and more stable bed in proportion to the height from floor, and in addition it permits of the use of large and heavy fly-wheels which give steadier running with less vibration and decrease to a minimum the liability of the motor stalling when operating under a heavy load. The operation of a horizontal engine is in no manner different from that of a vertical motor of the same type, and hence a further description is not necessary.

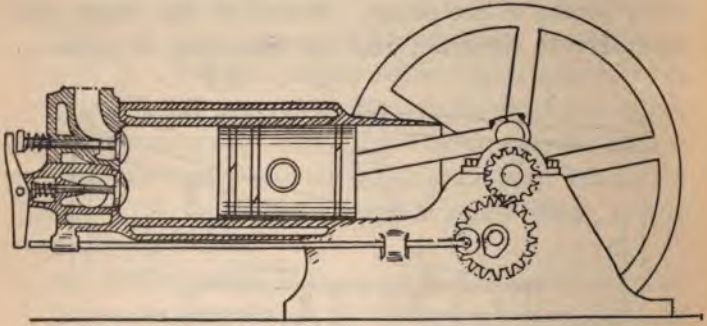


Fig. 37.—Horizontal Motor

CHAPTER IV

PARTS OF TWO-CYCLE MOTOR.—PARTS OF FOUR-CYCLE MOTOR.—COOLING METHODS; WATER- AND AIR-COOLED MOTORS.—DESIGN AND CONSTRUCTION OF MOTOR PARTS; CYLINDERS, PISTONS, PISTON-RINGS, CONNECTING-RODS, CRANK-CASES, JACKETS, SHAFTS, COUNTERWEIGHTS, BEARINGS, GEARS, CAMS AND VALVES, FLY-WHEELS; ACCESSIBILITY.

BY reference to the following figures and explanations of cuts it will be seen that the number of parts in the two- or four-cycle engine is not very great, but as many of the smaller parts, such as the various bolts, screws, nuts, pins, springs, washers, etc., are duplicated many times, the actual number of pieces used in an engine is very large. While the main parts, such as cylinder, shaft, piston, connecting-rod, piston-rings, crank-case, fly-wheel, etc., are identical in either type of motor as far as actual numbers go, and in multiple-cylinder engines are merely duplicated for each cylinder, the four-cycle motor has in addition numerous pieces of mechanism connected with the valve and cam shaft that are wanting in the two-cycle motor. The illustrations represent motors of both the water-cooled and air-cooled jump-spark type. Air-cooled motors have fewer parts owing to the absence of pump, water pipes, check valves, etc. (Fig. 39), while the make-and-break system of ignition requires more parts than the jump spark (see Fig. 40). All gasolene and internal-combustion engines require cooling of some sort to prevent overheating, warping,

Parts of Two-cycle Motor

(Jump Spark, Water-cooled)

A, Cylinder
B, Water Jacket
C, Piston
D, Piston Rings
E, Piston Pin
F, Connecting Rod
G, Crank Case or Base
H, Bearing Head or End Plate
I, Main Bearings
J, Connecting-rod Bearings
K, Piston-pin Bushings
L, Counterweights
M, Oil Duct to Connecting-rod Bearings
N, Crank
O, Crank Shaft
P, Timer Gears
Q, Gear Cover
R, Timer Shaft
S, Timer
T, Fly-wheel
U, Fly-wheel Locknut
V, Fly-wheel Key
W, Ball Thrust
X, Pump Eccentric
Y, Pump Plunger
Z, Pump Packing Gland
PK, Pump Packing
PB, Pump Body.
CV, Check Valves
DC, Drain Cock
FC, Firing Chamber
SP, Spark-plug Hole

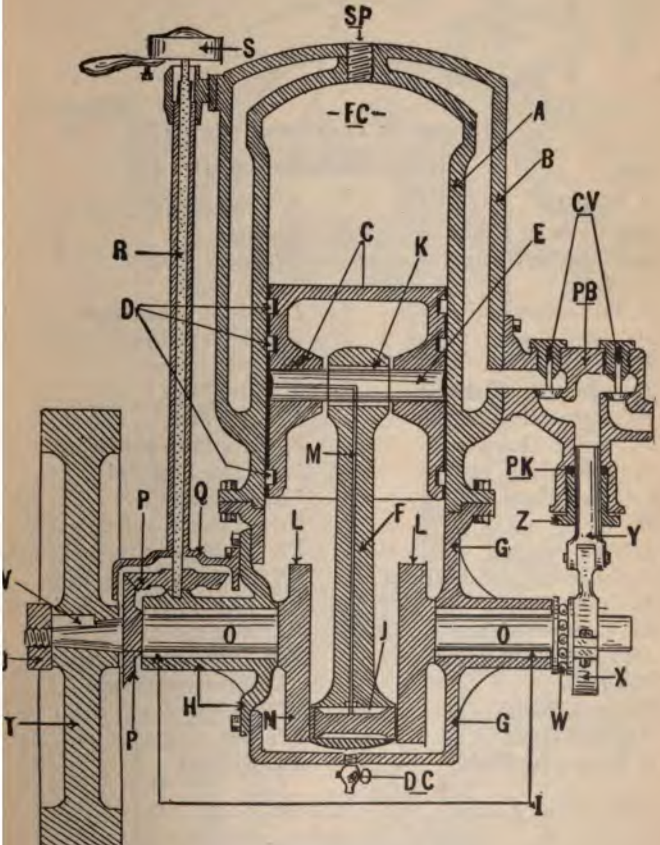


Fig. 38.—Parts of Two-cycle Motor
Water-cooled, Jump Spark

Parts of Four-cycle Motor

(Jump Spark, Air-cooled)

A, Cylinder
AH, Cylinder Head
B, Radiating Flanges
C, Piston
D, Piston Rings
DC, Drip Cock
E, Piston Pin
F, Connecting Rod
FA, Connecting-rod Cap
FC, Firing Chamber
G, Crank Case
GA, Base Plate
H,
I, Main Bearings
J, Connecting-rod Bearings
K, Crank Pin
LL, Counterweights
M, Valve Driving Gear
N, Crank
O, Crank Shaft
P, Timer Gears
Q, Valve-gear Shaft
R, Timer Shaft
S, Timer
SP, Spark Plug
T, Fly-wheel
U, Fly-wheel Locknut
V, Fly-wheel Key
W, Ball Thrust
X, Valve Gear
Y, Valve Cam
Z, Valve Push-rod Roller
ZA, Valve Push-rod
VE, Exhaust Valve
VEF, Exhaust-valve Foot
VEG, Exhaust-valve Stem Guide
VES, Exhaust-valve Stem
VET, Exhaust-valve Spring
VI, Inlet Valve
VIG, Inlet-valve Stem Guide
VIS, Inlet-valve Stem
VIT, Inlet-valve Spring
IV, Inlet
EX, Exhaust

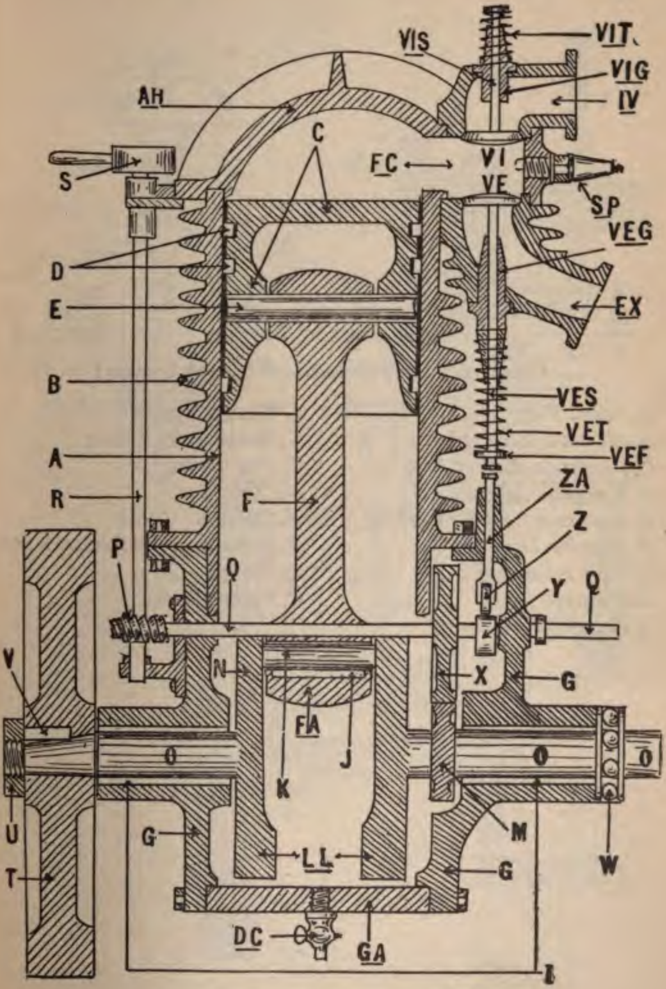


Fig. 39.—Parts of Four-cycle Motor
Air-cooled, Jump Spark

EXPLANATION OF FIG. 40

(Parts of Two-cycle Make-and-break System)

A, Spark Plug
B, Movable Electrode
C, Electrode Rocker Arm
D, Electrode Spindle
E, Electrode Spindle Bushing
F, Angular Dog
G, Trip Adjusting Screw
H, Plunger
I, Plunger Thimble
J, Plunger Spring
K, Rocker-arm Spring
L, Dog Spring
M, Slide Bar
N, Slide-bar Guide
O, Ecccentric and Eccentric Rod
P, Pump
Q, Pump Plunger

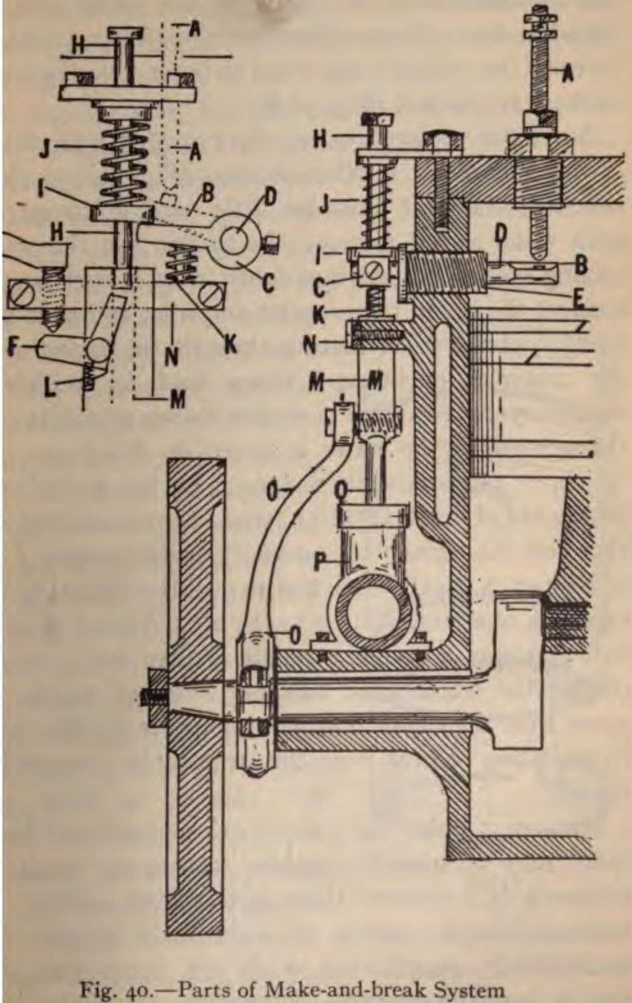


Fig. 40.—Parts of Make-and-break System

and seizing of the cylinders and pistons, and this is accomplished either by means of air forced past the cylinders by a fan or blower, or by water circulated between the cylinder proper and an outer covering known as the water jacket (Fig. 38 *B*).

Air-cooled motors are usually provided with flanges of thin metal cast on the cylinders (Fig. 39), to aid in radiating the heat, and are little used in comparison with water-cooled motors. In marine use the water-cooling system is used invariably, as it is very easy to connect the pump to an outlet and inlet and thus keep fresh, cool water circulating through the jacket while the motor is operating. When used for vehicle or stationary use a radiator or similar cooling system is used, through which the water is forced by the pump, and which, by numerous thin flanges or by thin-walled compartments of small capacity, tends to radiate heat and thus cool the water. In stationary engines a large tank, or hopper, is usually sufficient to cool the water through exposure of a large surface to the air. A sheet of cloth, wire gauze, or a perforated plate is often used to aid in cooling the water from stationary motors, as the hot water from the engine flowing over this is rapidly cooled by radiation of heat from the large surface exposed to the air.

Ignition of either the jump spark or make-and-break spark may be used in gasolene motors and as far as efficiency is concerned there is but little choice; the make-and-break system is electrically simple and mechanically complicated, while the jump-spark system is just the reverse—electrically complicated and

anically simple. Ignition systems will, however,
ealt with in detail in a following chapter and are
mentioned here in connection with the various parts
e motors.

e actual value, life, and power of a motor depend
st as much upon the quality of material used and
taken in the construction of its various parts as
its design and proportions. The cylinders are
nonly made of fine-grained cast iron, and after
g to the proper size should be ground to a mirror
and fitted to within
oo of an inch. The piston
vary considerably in shape
proportion with different
es and types of engines,
the general principle of
truction is the same, and
iron is principally used in
ing them. A perfect-fitting
n is essential to a good
r, for if too loose the
ression will be lost, where-
f too tight, it will bind
hot and score the cyl-
walls or prevent the
r from operating. It is
mary to test all pistons
cylinders by limit gauges;
f these gauges is 1/2000 of an inch oversize, the other
ame amount undersize, and if the parts fit the under-
gauge or fail to fit the oversize gauge they should be

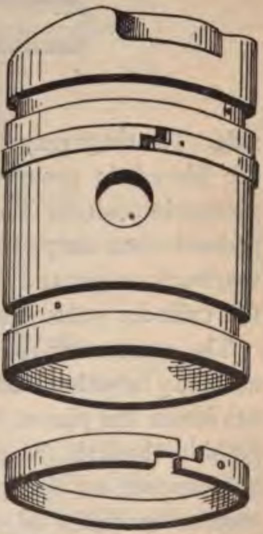


Fig. 41.—Piston and Piston Rings

discarded. The piston should not fit the cylinder too snugly, however, for allowance must be made for expansion when hot, and in order to allow for this and yet to retain gas under compression, piston rings are provided. These rings are made of cast iron and are turned and faced on a lathe, ground on the sides, and are then cut, clamped together, and ground on the faces. They are made eccentric,—thicker on one side than the other,—and are cut with a diagonal or lapped joint on the thinner side. The rings may be two, three, or four in number and are placed in grooves on the piston and are usually pinned in position (Fig. 41). The rings are slightly compressed when the piston is inside of the cylinder and their tendency to expand keeps them pressed firmly against the cylinder walls, thus forming a gas-tight joint.

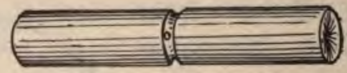


Fig. 42.—Piston-pin

The connecting-rod may be either of steel or bronze, and may be either cast or forged. The upper end, which fits inside the piston, is held in place by a hardened pin passing through the piston from one side to the other and known as the piston pin (Fig. 42). There are various methods of fastening this pin in place, but set-screws within the piston (Fig. 43, *S*) are perhaps the most satisfactory. Some makers bush the pin where it fits the piston walls and fasten the connecting-rod to the pin (Fig. 44), while others fasten the pin to the piston *and provide* a bearing surface for the connecting-rod head by placing a bronze bushing between the pin and connecting-rod (Fig. 45). The latter system is preferable as it obviates any danger of the pin working endwise and scoring the cylinder walls. The lower end of the connecting-rod is split, or cut, through the centre of the hole bored for the crank shaft, and a babbitt, or bronze, bearing fitted in place and the two parts clamped together around the crank shaft. There are various methods of fastening the bottom cap to the rod proper, but a hinge on one side and cap-screw with double nuts on the other is widely used (Fig. 46). Other makers used a loose cap held to the rod by screws on either side, and while this method allows of finer adjustment, it is not so convenient as the hinged cap (Fig. 47). Crank cases may be cast from iron, steel, aluminum or other metal, and may be made either solid, with one end removable (Fig. 48); with split base (Fig. 49); with both

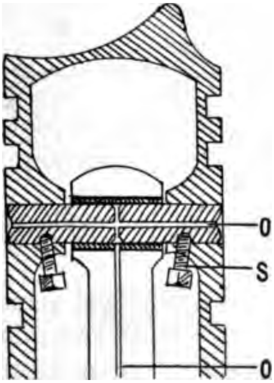


Fig. 43.—Piston-pin held by Set-screws

bearings or end plates separate (Fig. 50); or the upper portion of crank case and cylinder may be cast in one piece with a separate cylinder head held in place by bolts (Fig. 51); or a combination of two or more of the above may be used. In either case all joints should be turned and faced true and smooth and thin gaskets of paper, or similar packing, placed between the ground surfaces.

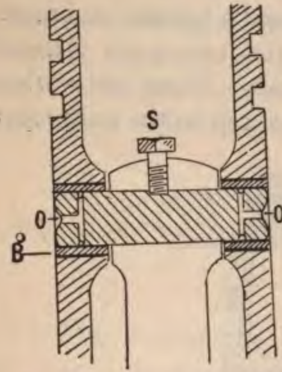


Fig. 44.—Piston-pin bushed in Piston

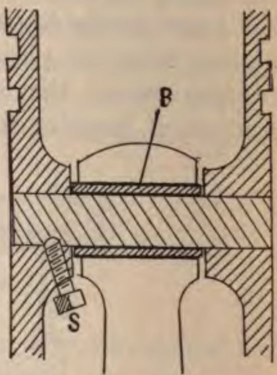


Fig. 45.—Piston-pin bushed in Connecting-rod

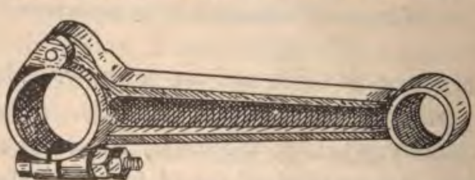


Fig. 46.—Connecting-rod with Hinged Cap

Crank cases are commonly furnished with hand-hole plates on the sides (Figs. 50, 51, *H*), and these should be *of ample size* to permit tightening or adjusting the connecting-rod bearing without taking down the motor; many motors are made in which the hand-hole plates are so small that they are absolutely useless. Of course, in four-cycle motors, the base being open and the entire side plates removable, there is no trouble in getting at the crank shaft.

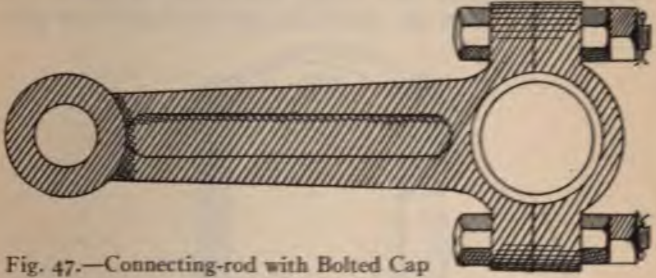


Fig. 47.—Connecting-rod with Bolted Cap

In small-sized motors it is often easier to remove the cylinder to reach the piston and crank shaft than to attempt working through a hand-hole in the base, but in large-powered and heavy motors the hand-holes are

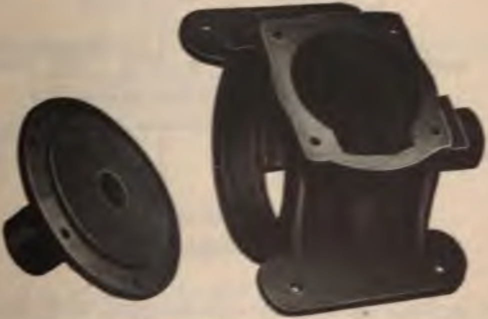


Fig. 48.—Base with One End Removable

preferable, and in this class of engines removable cylinder heads are a great convenience as they permit the piston being withdrawn through the cylinder by simply removing the head and disconnecting the connecting-rod from the shaft through the hand-hole plates.

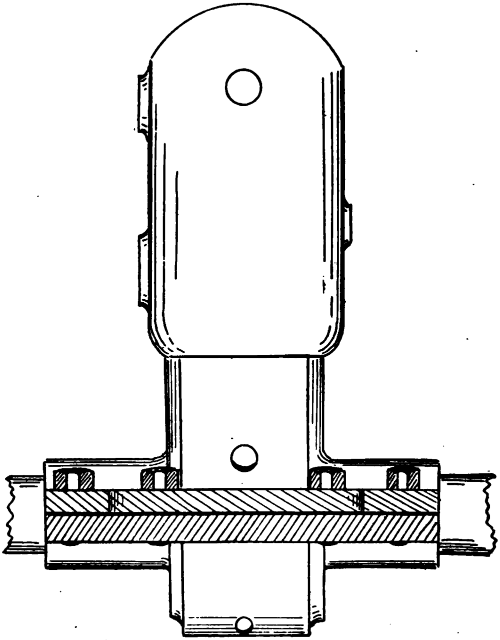


Fig. 49.—Split Base

Water jackets are usually cast integral with the cylinders (Fig. 38), but in a number of light-weight motors—especially those for vehicle use—the jacket is formed from spun copper or similar material and is clamped *over the cylinder*, leaving a space between the two

(Fig. 52). This method is very satisfactory where fresh water is used for cooling, but for salt-water use it is not advisable, as the salts in the sea-water set up galvanic action between the copper jacket and the iron cylinder

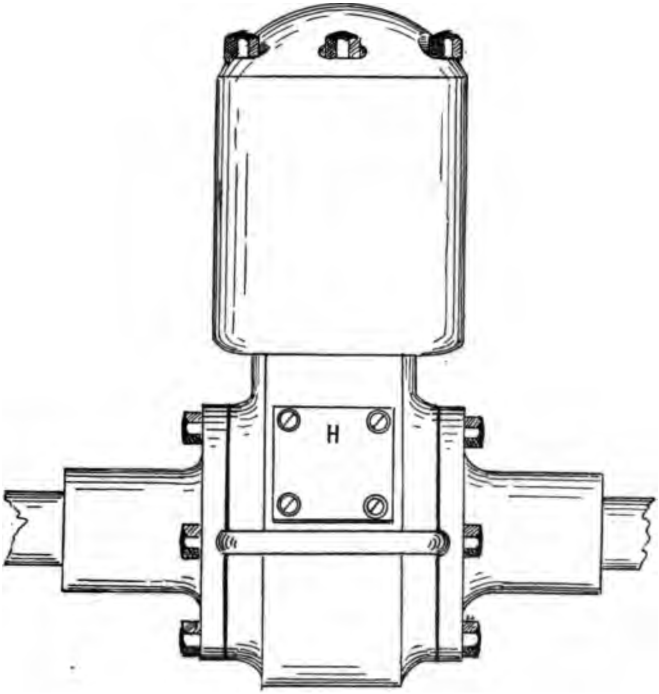


Fig. 50.—Both Ends of Base Removable

and this soon eats away the cylinder and causes rapid corrosion.

Crank shafts are perhaps too often neglected in the smaller and cheaper motors, and even in many of the larger sizes they are not given as much care and attention as they should have. Crank shafts bear all the strain and pressure of the explosive impulses and serve to transmit all the power to the machinery; they should therefore be designed with a large excess of strength and ould be forged from the highest grade of steel. Open-

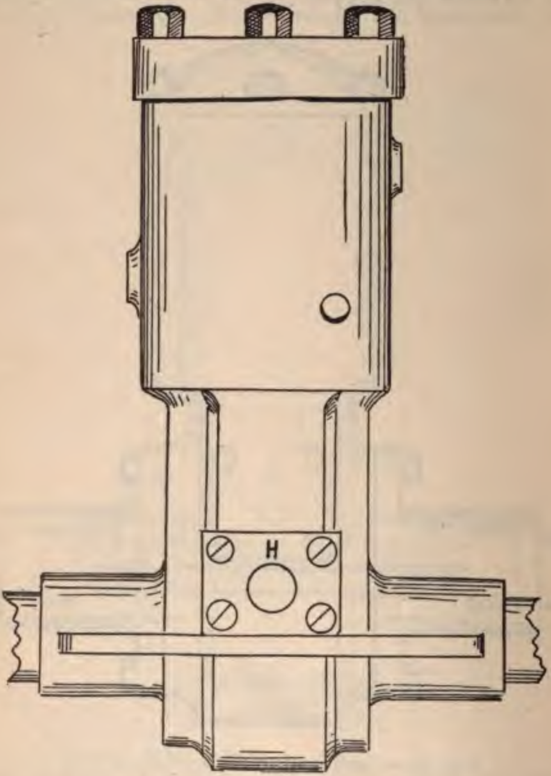


Fig. 51.—Cylinder with Separate Head

hearth .35 to .45 carbon steel is excellent material, and after forging into shape it should be annealed, which relieves the strain from forging and renders the steel tough and strong. They should then be machined to within 3/1000 of an inch in size, and finally ground to a mirror finish, where the bearings are to fit. Many otherwise good motors have cranks without counterbalances, but these are most essential to single-cylinder

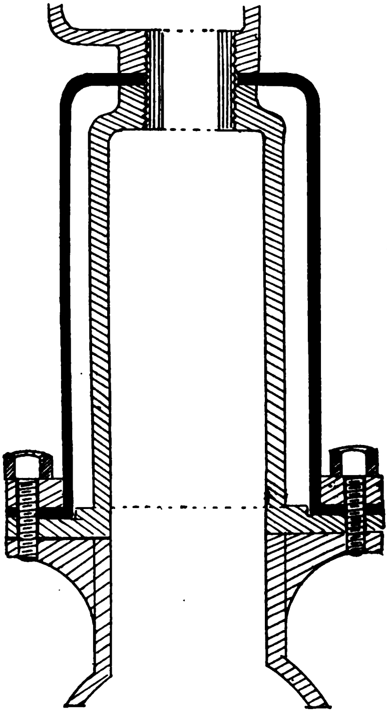


Fig. 52.—Water Jacket Clamped On

motors if smooth running and lack of vibration are desired. There are many methods of fastening counterweights to crank shafts, some of which are shown in Fig. 53. Malleable-iron weights fitted to the crank and dowelled and riveted answer very well and are widely used (Fig. 54). This is the method adopted by the Gray Motor Co. Bearings are most important parts of a motor, and various materials are used by different makers. Babbitt, bronze, white-bronze, and various special alloys are utilized, and each has its advantages and disadvantages. Babbitt is excellent, if of very high grade, but will melt and cut badly if improperly lubricated or overheated. Bronze will wear well and will stand considerable heat, but will cut and injure the shaft or other moving parts if allowed to run dry or wear loose. Whatever material is used, the fit should be perfect and the bearings so constructed that they are easily removable and interchangeable. The Gray Motor Co. uses a very high grade special babbitt, and the main bearings *are very long* and so constructed that they are removable

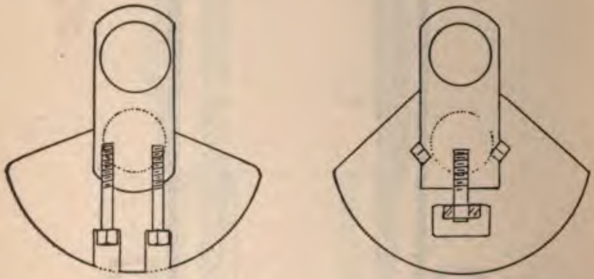


Fig. 53.—Methods of Fastening Counterweights

and interchangeable in a few moments (Fig. 55). In a two-cycle motor the size and length of the main bearings are very important, for if worn or loose the crank compression will be lost and the motor's efficiency destroyed.

Gears, timer parts, and all water connections on marine motors should be of bronze, or similar metal, to prevent rust and corrosion; and if quiet-running gears are desired they should either be made in pressure die moulds from bearing metal or should be made with fibre or rawhide inserts or with slanting or helical teeth (Fig. 33). The particular kind of gears used depends largely upon the

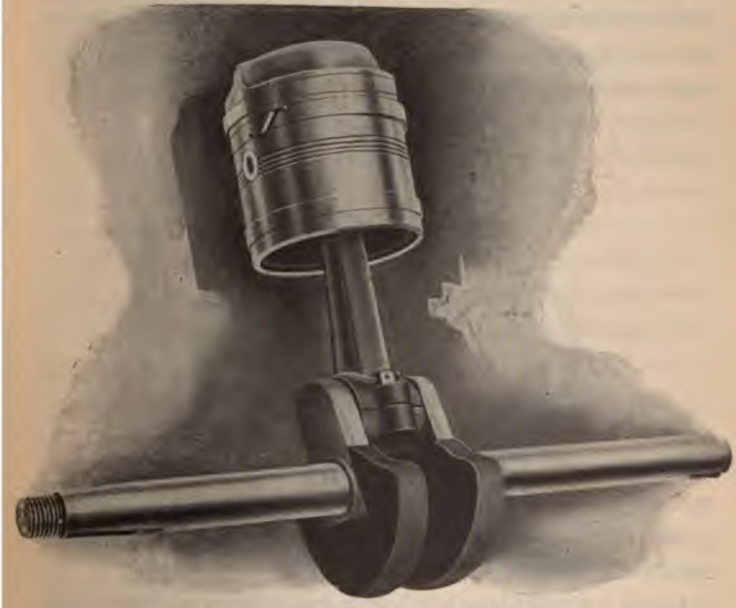


Fig. 54.—"Gray" Counter Weights

experience and personal choice of the manufacturer. Some use one kind and some another, but iron or steel gears are to be avoided as far as possible unless of the worm or helical type, for bevel or spur gears of these metals are invariably noisy and wear rapidly. The bearing-metal gears used in the "American motors" run very quietly and give excellent results. These gears are cast in special moulds and are formed under several tons' pressure. Other makers obtain equally good results by using fibre inserts in the teeth, or by taking great care in cutting all gears on special machines which insure the utmost accuracy.

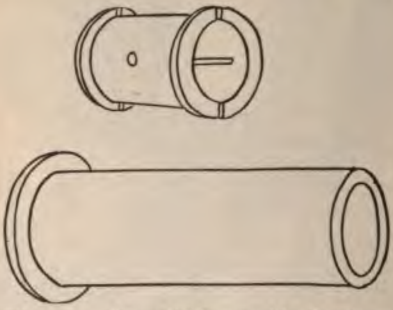


Fig. 55.—"Gray" Removable Bearings

Cams for operating the valve mechanism of four-cycle motors should be of case-hardened steel, and the same metal should be employed wherever severe friction or continual pounding occurs, as on push-rods, valve-stem feet, rocker arms, etc. Valves are made of various materials, but the best forms are those forged from high-grade nickel steel. Cast-iron valves with steel stems *riveted in place* were formerly used, but it well repays any motor-owner to replace all such valves with new ones forged from the best quality steel.

Accessibility in a motor is a very important matter and one that is all too often overlooked. Many motors of excellent design and most careful construction are so assembled that in order to get at some small minor part it is necessary to take down the entire motor. Of course it is practically impossible to build a motor in which every part can be removed without disturbing some other part, but the nearer one can come to this ideal condition the better. Cylinders should be removable without disturbing the base or shaft, and all piping and water connections should be so arranged that they can be easily removed or disconnected without disturbing the rest of the motor. In this connection the fly-wheel is of considerable importance, and in many motors this is very difficult to remove, although, in order to reach the gears or pump eccentric, it is necessary to remove it. Wheels that are fitted to a straight shaft and keyed in place often rust fast to the shaft and are almost as solid as if a part of it. While it is absolutely necessary to have the fly-wheel tight, to avoid vibration and pounding, yet it should be fastened in such a way that it can be taken off without special tools or machinery. Several makers use a tapered end to the shaft fitted in a tapered hole in the fly-wheel. The wheel is forced on the taper by a large nut and is prevented from slipping by a key (Fig. 56). Such wheels are usually easy to remove, but a still better plan is to use a bushing of bronze between the shaft and the wheel, as this prevents the iron wheel from rusting to the steel shaft (Fig. 57).

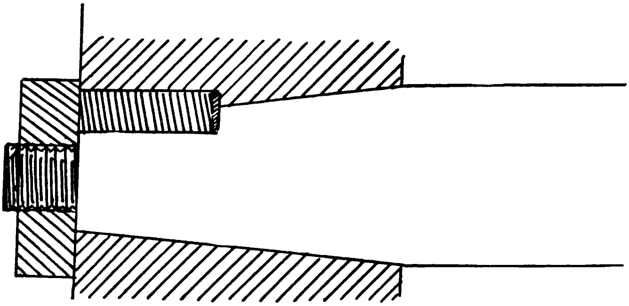


Fig. 56.—Tapered Fly-wheel Shaft with Key

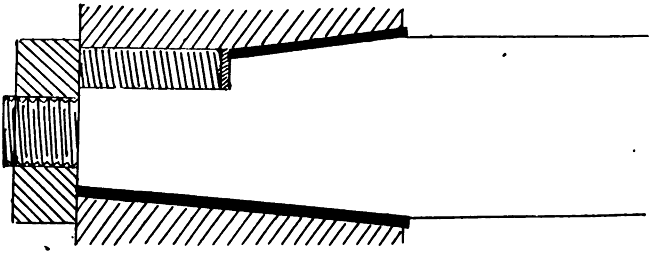


Fig. 57.—Tapered Fly-wheel Shaft Bushed

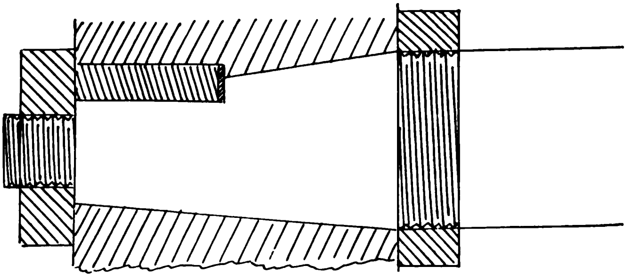


Fig. 58.—Tapered Fly-wheel Shaft with Releasing Nut

Still another method which renders the wheel easy to remove is illustrated in Fig. 58. This consists of a tapered shaft with shoulder *A*, which is threaded and provided with a nut *B*. The wheel is forced up on the taper and shoulder as in the ordinary tapered shaft and the nut *B* is then set up against it. When the wheel is to be taken off the forward lock-nut *C* is removed, and by turning the rear nut *B* against the wheel the latter is easily forced off the shaft. This idea is original with the author and has been employed on several motors with great success. Even with a straight shaft and key the rear nut will force the wheel from the shaft unless very badly corroded.

CHAPTER V

MOTOR ACCESSORIES—VAPORIZERS—CARBURETORS—COOLING SYSTEMS—FANS AND PUMPS—CIRCULATING DEVICES—LUBRICATION—GRAVITY AND FORCE-FEED OILERS—GREASE CUPS—OILING SYSTEMS.

ALL attachments and parts of a gasolene engine, not actually a part of the motor itself, may be classed under the general head of Accessories, for while these various devices may outnumber the parts of the motor and the latter may be incapable of operating without them, yet they are seldom manufactured by the motor manufacturers and often are of equal importance and of greater value than the bare engine. In fact a motor without accessories is no better than so much old metal, as far as use is concerned. Nevertheless, many owners or operators of gasolene motors who are very careful to purchase or use the best motor that money can buy are very careless or indifferent where the attachments or accessories are concerned. In reality most failures of gasolene motors to give satisfaction are due to faulty or poorly constructed or obsolete accessories. The best motor in the world will not operate properly with poor ignition or poor vaporizing devices, whereas a poor motor will often work fairly well if furnished high-class ignition and fuel-mixing apparatus. Every gasolene motor must be supplied with some sort of device for furnishing the *explosive gas* and for so combining the air and fuel as to form the proper mixture or "gas" to give the greatest possible explosive force without waste of fuel.

Such devices are known as mixers, carburetors, or vaporizers, and they may be roughly divided into three groups: Vaporizers, Float-feed Carburetors, and Mechanically operated Mixers. Gasolene, benzine, kerosene, alcohol, or any other liquid fuel must be vaporized or transformed into an explosive gas by mixing with air before it can be utilized as a fuel for internal-combustion engines. The function of either mixers, carburetors, or vaporizers is to create a mixture of gasolene or other fuel with the air in such proportions as to give the highest efficiency. Vaporizers as a rule are cheaper and simpler than carburetors and are not nearly as satisfactory. A common form is illustrated in Fig. 59. In this cut A

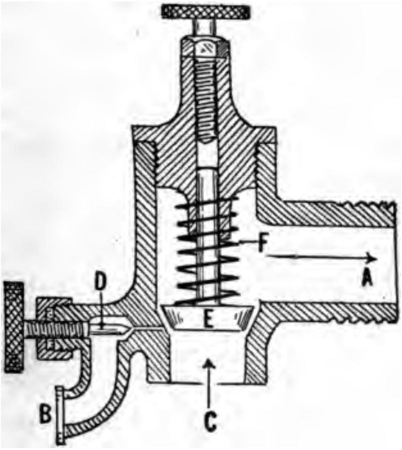


Fig. 59.—Vaporizer

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represents the inlet to motor; *B*, the gasolene supply pipe or inlet; *C*, the air intake; *D*, the needle valve; and *E*, the check valve. The gasolene flows through the opening of the needle valve *D* and the amount admitted to the motor is varied by screwing the valve up or down. While the check valve *E* is held on its seat by the spring *F*, the opening of the needle valve is closed and no gasolene flows through. As soon as the motor commences to operate the suction through the inlet *A* draws air through the inlet *C* and this suction raises the check valve from its seat, allowing a small jet of gasolene to run into the vaporizer. This gasolene is mixed with the air as it rushes through from *C* to *A* and passes into the motor in the form of a vapor or fine spray. By varying the adjustment of the needle valve *D* and the lift of the check valve *E*, the proportion of gasolene to air can be varied to suit the speed or condition of the motor. In theory this system is excellent, but in actual operation it often proves faulty.

The best form of fuel mixer is undoubtedly the float-feed carburetor. A number of makes of these carburetors are on the market and each has its own good points and advantages. The operation of all is very similar and if one is thoroughly understood the others are easily mastered. A form in common use and which invariably gives most satisfactory results is known as the "Schebler." This carburetor is made in several forms and types, varying in the arrangement of air and gasolene supply and regulating devices, but the simpler form known as "Model D" is as satisfactory for general use as any *and is far easier* to understand than the more complicated models. This carburetor is illustrated in Fig. 60, in which *R* represents the inlet to motor; *G*, the gasolene pipe inlet; *A–C*, the air intake; *D–E*, the needle valve; *O*, the automatic air valve; *F*, the float; and *H*, the float valve. The flow of gasolene fills the float chamber *B* until the float *F* rises upward and shuts off the supply by the float valve *H*. As long as the motor is inactive this level remains constant and no gasolene passes into the motor. As soon as the piston moves on the suction, or intake, stroke a current of air is drawn through *C* and across the opening of the needle valve towards the motor

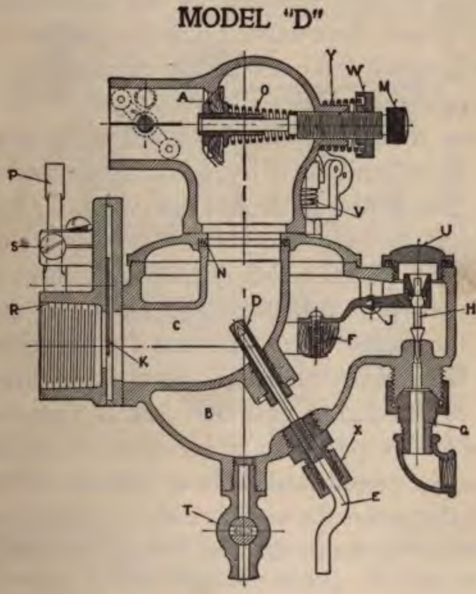


Fig. 60.—Schebler Carburetor

inlet *R*. This draught of air sucks a small quantity of gasolene from the opening of the needle valve and this, gathering upon the walls of the air passage, rapidly evaporates and is readily combined with the inrushing air and converted into an almost dry gas or vapor. The small amount of gasolene drawn from the full chamber is at once replaced by the automatic action of the float and float valve. The proportion of air to gasolene is easily and accurately regulated by means of the needle valve and air valve, *D* and *O*. It is usual to regulate the supply for the motor while running at medium speed and then by speeding up and slowing down so adjust the automatic air valve *O*, by means of the thumb nut *W*, that the best results are obtained at all speeds. The function of the check valve which is attached between carburetor and engine is merely to prevent the vapor in motor base from rushing back through the carburetor instead of upward through the by-pass to the firing chamber. It is therefore only necessary on two-port, two-cycle motors, for in the three-port type the piston itself acts as a check valve, while in four-cycle motors the mechanically, or spring, actuated intake valve prevents any backward pressure of the gases.

This carburetor, as well as those of other makes and most vaporizers, is also provided with a throttle valve *K*, operated by a lever *P*, and which shuts off all or a portion of the gas entering the chamber of the motor by closing the opening *R*. This lever may be so adjusted by the set-screw *S* that the throttle cannot be completely closed, but will serve to feed just the right amount of vapor to operate the motor at the slowest possible speed.

Another excellent carburetor of the float-feed type is the "Krice" illustrated in Fig. 61. In this carburetor *C* is the motor connection, *D* the cylindrical throttle; *E* the annular gasolene openings; *F* the gasolene level and float; *G* the gasolene bowl; *K* the needle-valve adjustment; *L* the throttle lever; *M* the air intake; *R* the inlet valve operated by the float; *T* the gasolene connection; *U* the needle valve; and *V* the drain cock. The advantages claimed for this carburetor are that the gasolene, instead of being drawn from the needle-valve opening direct, is drawn through a narrow slit or opening nearly three inches in circumference and 1/100 of an inch wide and is vaporized within the chamber H, thus

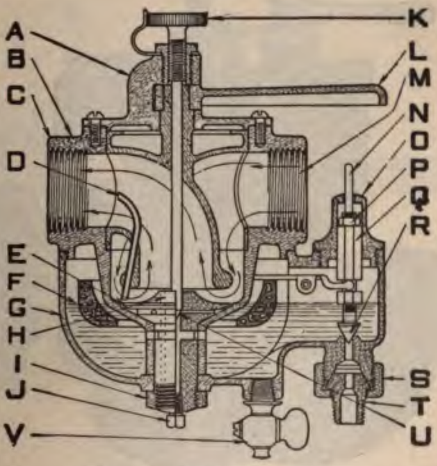


Fig. 61.—Krice Carburetor

producing more rapid evaporation and drier gas. The throttle *D* is also novel, being semi-cylindrical in form, and not only acts as a throttle, but also as an air adjustment for varying speeds of the motor.

Still another excellent type of float-feed carburetor

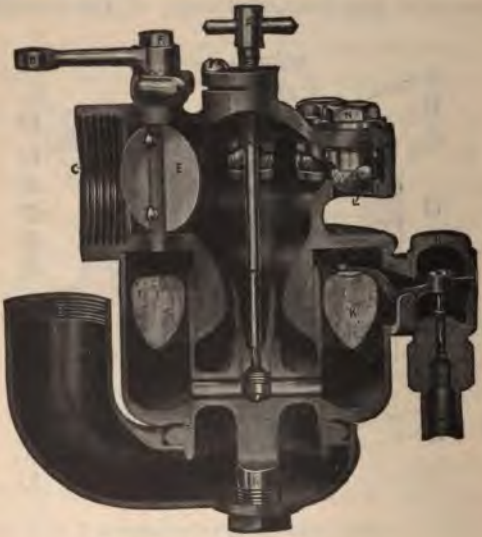


Fig. 62.—Kingston Carburetor

is the "Kingston" illustrated in Fig. 62. This carburetor acts on the same general principle as those already described, but has five supplemental air-supply inlets which are automatically opened and closed by bronze balls *M*, which float within the retainers *N* at high speeds, but close against their seats at slow speed, thus doing away with the more uncertain spring action of other automatic air-regulating devices. As a rule the simpler and more positive the better in carburetor design, for a slight derangement in any part will result in variation of mixture and loss of power or stoppage of the motor.

A form of mechanically operated mixer is shown in Fig. 63, which represents the mixer used on the Cadillac single-cylinder automobiles. In this cut, *A* represents the inlet to the motor; *B* the gasolene inlet; *C*, the air intake; *D*, the needle valve; *E*, the diaphragm; *F*, the valve seat; *G*, the adjusting screw; *H*, the mixer binder; *I*, the needle-valve spring; *J*, the binder screw; and *K*, the adjusting-screw binder. In operation the air, drawn inward by the suction stroke of the cylinder, causes the diaphragm *E* with the needle valve attached

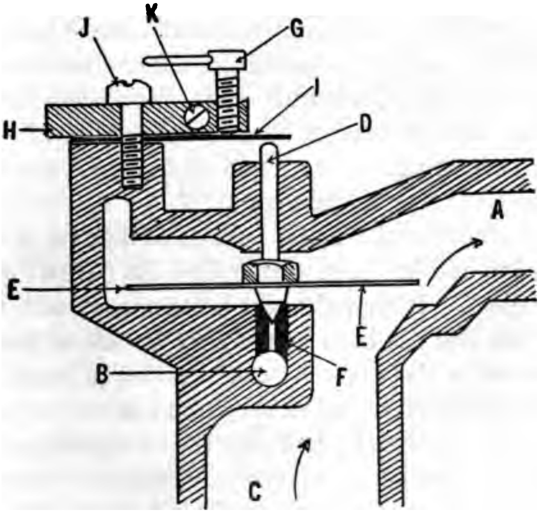


Fig. 63.—Mechanical Mixing Valve (Cadillac)

to lift from the valve seat and thus permit a small quantity of gasolene to escape and mix with the inrushing air. The screw *G* bears upon a spring *H* which presses upon the top of the needle-valve stem, and this spring and screw are adjustable by means of the binder *H* and screw *J* so that the spring exerts greater or less pressure upon the needle valve and thus allows it to raise higher or lower according to the requirements of more or less gasolene. When correctly adjusted this mixer gives excellent results, but the adjustments must vary with climatic variations and the conical head of the needle valve and its seat become rapidly worn and often permit too much gasolene to enter the chamber.

The carburetor of a motor is its most delicate piece of mechanism and has been aptly called the "Heart of the Gas Engine." It should never be tampered with until everything else has been looked over in case of trouble, for it is often the work of several hours to readjust a carburetor correctly. It is a very common fault of many operators to continually fool with the carburetor or even to use it to turn off the supply of gasolene by screwing the needle valve onto its seat. This is a practice that cannot be too strongly condemned. Turning the needle valve against its seat injures both valve and seat and it is practically impossible to adjust it once it becomes rough, burred, or bent. A regular cut-off valve or cock should be placed in the pipe line outside the carburetor, and this should always be used for shutting off the fuel supply when the motor is not in use. A great deal of trouble with carburetors is caused by water, or particles of dirt, getting in the gasolene and finding its way into the needle valve. A gasolene-strainer should be placed between the fuel tank and carburetor, but even this will not always prevent foreign matter from working into the valve. Practically all float-feed carburetors have a drain cock at the bottom of the chamber, and this should be frequently opened after the motor has stood idle for some time and the gasolene allowed to run off. If the gasolene thus drained is caught in a glass bottle or similar vessel you will be surprised to find how much water or dirt frequently drains off. On multiple-cylinder motors it is often customary to use a single carburetor with the intake pipe or manifold attached to the several cylinders. This system often works to perfection, but in other cases a separate carburetor attached to each cylinder proves far more satisfactory. Frequently on two-cycle, two-port motors apparent carburetor trouble is due to the check-valve spring being either too weak or too stiff. It usually pays to have several springs of varying strengths on hand and by experimenting with these excellent results may often be obtained when it is impossible to get satisfactory operation through carburetor adjustments alone.

A very important part of the motor is the cooling system. In the case of air-cooled motors a simple fan driving the cool air across the motor is all that is required, and this is so simple and so easily watched that any tendency to overheat can be easily attended to. In the case of water-cooled motors the system is far more complicated, and overheating may be caused by some portion of the cooling system failing to operate where it is very difficult to locate it. A very simple system of water-cooling used in many stationary motors, and in some vehicle motors, depends upon the well-known fact that hot water rises, and by placing a hopper, or radiator, at an elevation slightly higher than the motor

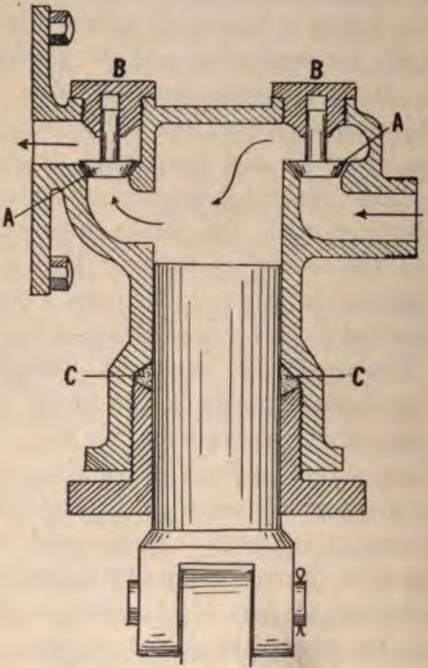


Fig. 64.—Plunger Pump

and connecting it to the water jacket the water continually flows through the motor about the cylinder. This system does not prove very satisfactory with two-cycle motors, as in this type of engine the explosion at every revolution tends to heat the cylinder walls far faster than in the four-cycle motors where an explosion only occurs at every other revolution, thus allowing the motor to cool off appreciably between the explosions. Usually a pump of some sort is used to force the water through the jacket and around the cylinders. This pump may be either of the plunger type (Fig. 64), of the gear type, or of the true rotary type. The plunger type of pump is very satisfactory where clear water is used, but in marine use it frequently becomes clogged by bits of seaweed, shells, gravel, or other matter becoming wedged between the check valves (Fig. 64, *A*, *A*) and their seats. This is readily removed by unscrewing the check-valve caps (Fig. 64, *B*, *B*).

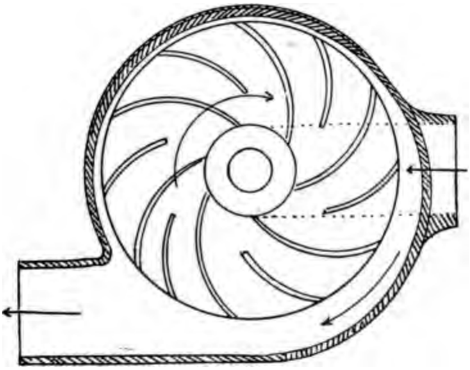


Fig. 65.—Rotary Pump

In addition to this trouble the plunger pump is usually noisy and requires packing around the plunger (Fig. 64, *C*, *C*) in order to keep the pump from sucking air. Even when the plunger packing is as tight as it can be made without offering great resistance, there is apt to be quite a little leakage of water which is extremely objectionable. In vehicle use the impracticability of keeping this type of pump tight has led to the almost universal adoption of some form of rotary pump. The true rotary pump is a very simple affair and may be driven by belt, cog-wheel, sprocket-and-chain, or by similar mechanical means; it has the advantage of operating noiselessly and, moreover, can be placed at

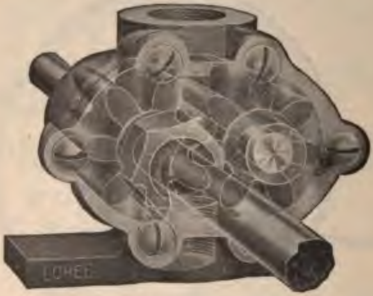


Fig. 66.—"Lobee" Gear Pump

some distance from the engine or where most convenient. A common form of this pump is shown in Fig. 65, but the shape of the paddles or interior fans varies with different makes. This style of pump circulates a large quantity of water at low pressure, and where a longer pipe line is used or where there is danger of dirt or other matter partially clogging the circulating system the gear pump is preferable. The Lobee gear pumps are typical of this class of circulating pumps, and one of these is illustrated in Fig. 66. These pumps *may be driven* in either direction, but the water will always flow in the direction of revolution as indicated by the arrows in Fig. 67, *A*, *B*. For this reason a check valve should be placed between the engine and pump when a motor is frequently reversed, for otherwise air may be drawn into the intake pipe and an air-lock formed which will prevent the pump from working satisfactorily until the air is forced out and the pump primed,

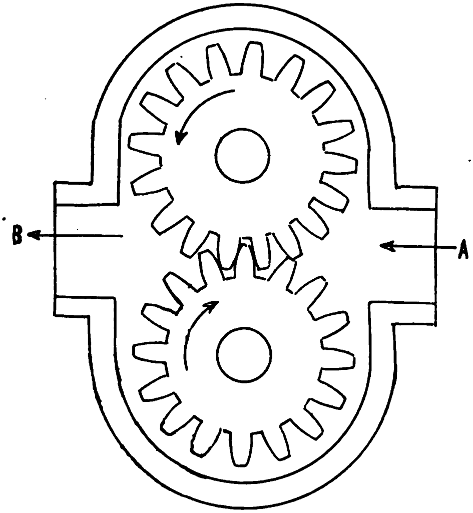


Fig. 67.—Flow of Water in Gear Pump

by pouring or forcing water through it and the pipes. Marine engines should always be provided with two check valves on the water pipe, one between pump and intake in boat and the other between the pump and water jacket (Fig. 38, *CV*). These prevent the water from flowing back from the cylinder through the pump, thus causing air in the pipes, and also prevent the boat

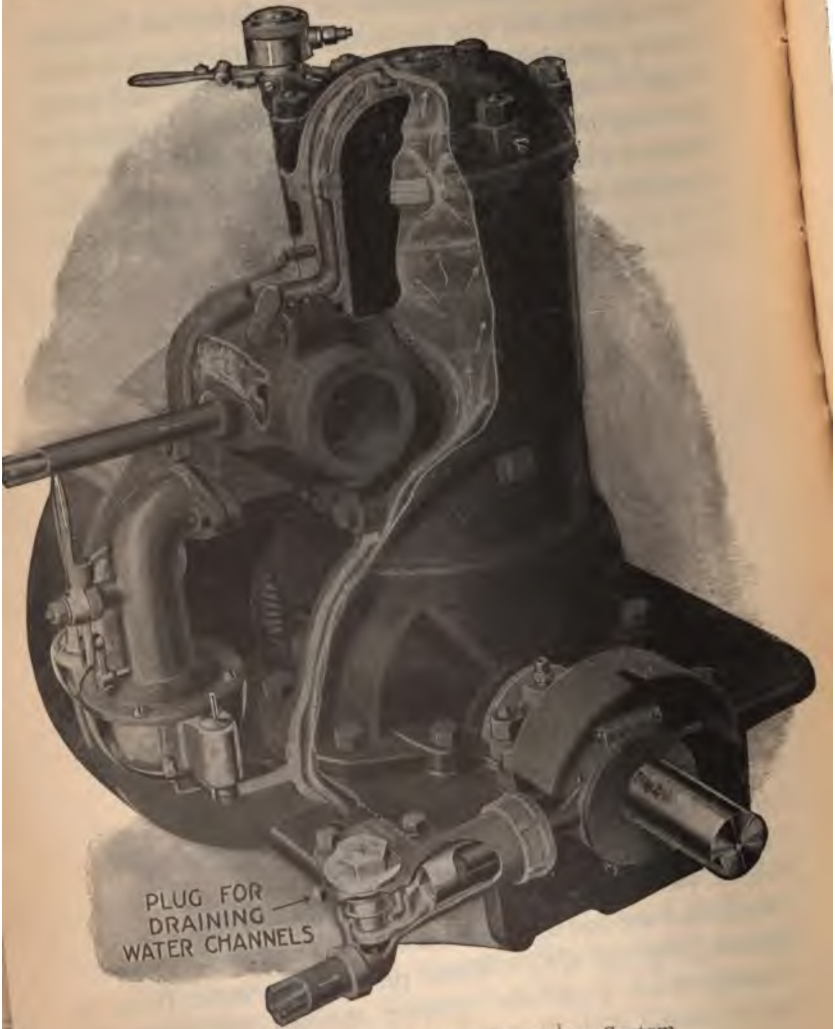

PLUG FOR DRAINING WATER CHANNELS

Fig. 68.—"Ferro" Water Circulation System

from flooding if the pump, engine, or pipes are below water line. With a rotary pump it is a good plan to have a cock or valve at the pump, or close to it, as in this way the pump can be primed, or oiled, through the cock without trouble. Both plunger and rotary or gear pumps should also be provided with a drain cock at the lowest point, from which all water may be drawn in cold weather to prevent freezing, and there should be a test cock between pump and engine so that by merely opening this the operator may readily ascertain if the pump is operating properly.

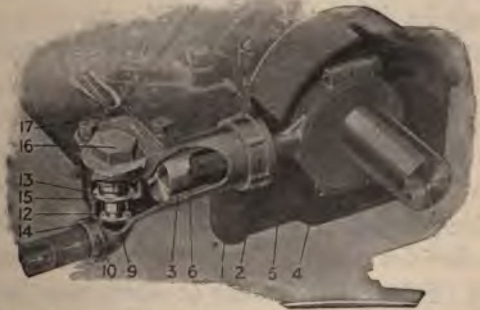


Fig. 68 *a.*—"Ferro" Water Circulating System

The water-cooling system in the Ferro engines (illustrated in Fig. 68) is unique and is well worthy of consideration. In these motors there is no exposed piping or connections as the water from the intake is pumped directly into the water jacket by means of a plunger pump directly connected to the shaft. In the illustrations the system of circulation as well as the simplicity of the pump are plainly shown. After leaving the pump the water is forced through a channel in the crank case and hence up to the jacket. Entering the water jacket the water divides and passes up on both sides of the exhaust port and then up and around the cylinder to the cylinder head, from which it passes into the exhaust manifold. It can then be piped either directly to a tank, to the outboard connection, or can be led into the exhaust pipe. At the lowest point in the water channel in the crank case there is a drain cock from which all water may be drained from the cylinder.

Almost as important as the vaporizing system is the lubrication equipment, for if allowed to run dry, or with too little oil, a gasolene motor will at once heat up and will soon be ruined beyond repair. If fed too much oil, carbon will accumulate in the cylinder, on the piston and valves, and will even choke up the muffler and exhaust, besides causing a disagreeable odor and excess of bluish smoke. Lubricators or oilers may be divided into three groups: gravity oilers, force-feed oilers, and grease cups. Gravity oilers consist of a tank or other receptacle to hold the oil, with pipes running to the various points of the motor requiring lubrication. They operate by the oil dripping through from the reservoir by gravity, and in order to aid in their operation a small ball check is usually placed at the top of the oil pipes. This class of oilers is in general use and they may consist of either a large tank from which numerous pipes lead, or may be merely independent oil cups. Several makers now have glass-bodied oil cups with several feeds, as illustrated in Fig. 69. For small or single-cylinder motors these oilers answer all requirements, but they require frequent refilling and the best of them are apt to leak oil and become greasy and dirty.

Force-feed oilers are very different in principle and construction; they consist of a tank or receptacle for the oil, within which is a compact oil pump operated by a lever, pulley-wheel, or gears connected to the engine, and this pump forces the oil through the pipes to the proper points. As the pump will force the oil against high pressure there is no danger of the pipes becoming clogged or the oil failing to reach the bearing surfaces. On some portion of the oiler there are small tubes, enclosed by glass, through which the oil is forced in drops in exactly the quantity that it is fed to the engine. This acts as a sight feed, and by means of plungers, or screw adjustments, the flow of oil to any or all pipes may be regulated to feed the proper amount. On large-size, multiple-cylinder, vehicle motors or any motor that operates for some time without continual observation, the force-feed system is a necessity, and although the first cost is more than for the gravity oilers the results are fully worth the additional outlay. An excellent type of this class of oilers is manufactured by the Detroit Lubricator Co. (Fig. 70), while those of the Osgood

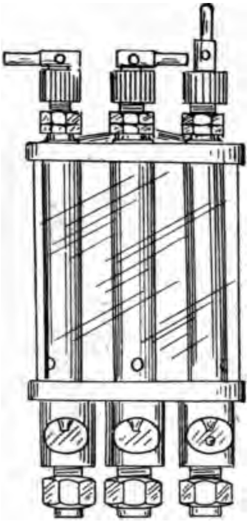


Fig. 69.—Multiple-feed Oiler

Lubricator Co. are illustrated in Fig. 71. Grease cups are used on bearings, shafts, and smiliar places, and consist of a cup which is filled with grease that can be forced onto the bearings by means of a plug, or plunger, screwed into the cup (Fig. 75). For marine and stationary work these grease cups answer very well, but if the motor is provided with a force-feed lubricator or a tank gravity-feed oiler it is better to oil the bearings by the regular lubricator pipes. The principal points for lubrication are the piston, piston-pin, connecting-rod bearing, main bearings, and, in four-cycle motors, the gears, cams, and push-rods.

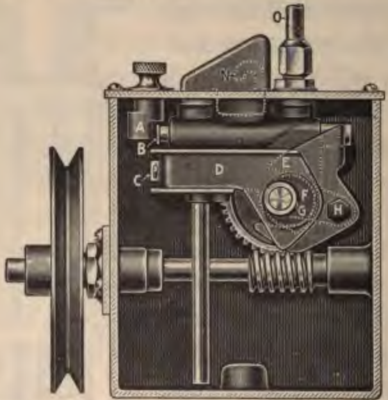
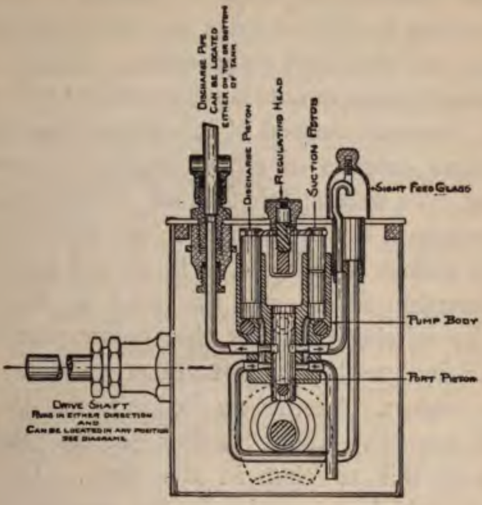


Fig. 70.—"Detroit" Force-feed Lubricator

The proper amount of oil to be fed depends largely upon the size and speed of the engine and its age and care. A new motor will require more oil than one which has been operated for some time, while an engine that has *become badly* worn, and loses compression, may often



Sectional View

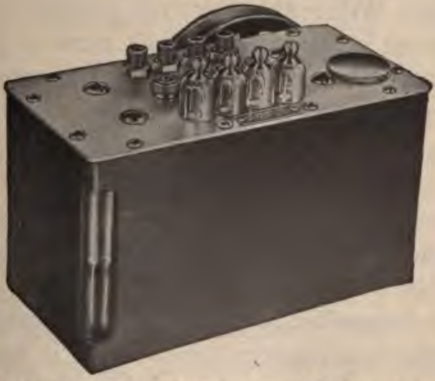


Fig. 71.—"Osgood" Force-feed Lubricator

be made to operate far better by feeding an excess of oil which serves to fill the leaks around piston rings and bearings and thus hold compression. Usually from six to fifteen drops per minute is sufficient for a well-cared-for motor. Another method of lubrication that has many advantages consists of oiling the motor through the gasolene. To accomplish this, oil should be added to the gasolene in the proportion of one pint of oil to five to eight gallons of gasolene. The oil and gasolene must be thoroughly mixed and this may be accomplished either by stirring them together before placing in the tank or by pouring both together through a funnel with a strainer. Another method is to mix the oil with a small quantity—about a gallon—of the gasolene and then add this to that in the tank. The oil thus mixed is held in suspension in the gasolene in minute globules, and passes with the gasolene through the carburetor. Within the motor the gasolene is vaporized, while the oil is deposited over all parts of the interior of the motor, thus lubricating it very thoroughly. This method gives excellent results but has numerous disadvantages. If one has a private gasolene supply where the oil may be properly mixed in known proportions there is little trouble, but if you purchase oil or gasolene here, there, and everywhere—as is necessary when on a cruise with a boat or on a long automobile trip—it is next to impossible to get the proper proportions every time; either too much or too little oil is sure to result under such conditions, and in addition it is considerable trouble to stop and mix the oil and gasolene every *time the tank* is refilled. Moreover, the oil passing through the carburetor has a tendency to keep the carburetor oily and accumulate dirt, while oftentimes the oil becomes gummy and hard from cold weather, or from the cold generated by evaporation on the carburetor, and the latter then becomes clogged and fails to operate properly. In four-cycle engines the oil often accumulates on the valve stems and causes them to stick, or is forced into the exhaust pipe and muffler, causing clogging and soot.

The most difficult parts of a motor to lubricate successfully are the piston-pin and crank-shaft bearing of the connecting rod, and this is accomplished in various ways. A common and good method is to have a hole bored through the piston-pin and another through the connecting rod connecting with the former. The oil, fed into the cylinder, lubricates the piston and also enters the hole in the piston-pin and, after lubricating the bearing at the head of connecting rod, finds its way down to the crank shaft. This method is excellent on small to medium-sized engines and is well shown in Figs. 38, *M*; 43 and 44, *O*; and in Fig. 74.

To lubricate the crank-shaft bearings still more effectively a splash system is used in many motors in which a quantity of oil is kept in the bottom of the crank case and into which the connecting-rod cap and crank shaft dips at each revolution, thus splashing the oil about and lubricating the various internal parts. Practically all two-cycle motors lubricate more or less on this principle, for there is always an excess of oil accumulating in the base into which the crank dips. To more evenly distribute the oil in the base a system of oil rings oil up to the distributor. As a constant pressure is maintained in the tank only a very slight additional pressure is required to force oil to the sight feeds and hence to the various points requiring lubrication. Aside from adjusting the needle valves on the distributor and keeping the tank full of oil, this device requires but little attention and is practically automatic; operating when *the motor runs* and ceasing as soon as the engine stops.

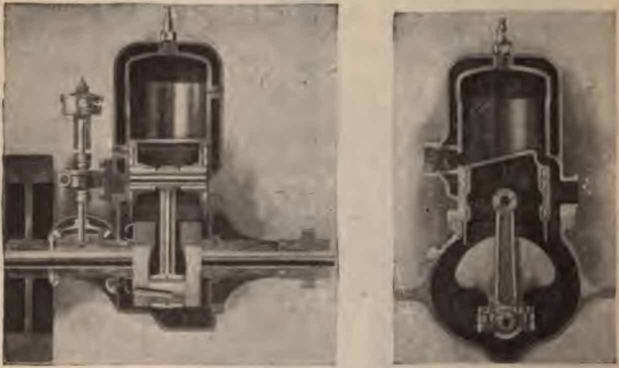


Fig. 74.—"Gray" Lubricating System

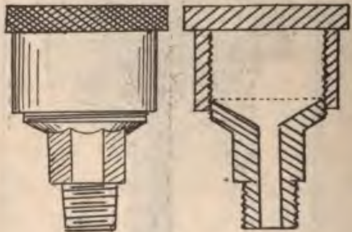


Fig. 75.—Grease Cups

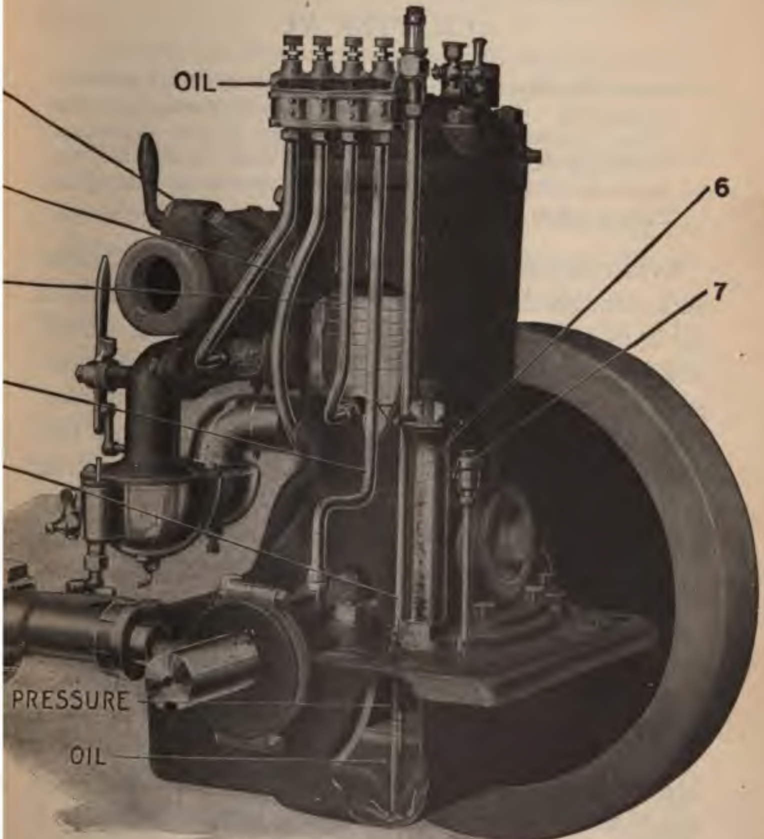


Fig. 76.—"Ferro" Lubricating System

The two general sources of electricity for ignition are wet or dry cells and magnetos or dynamos. A storage battery does *not* generate electricity but merely stores that generated by a dynamo or other apparatus. By passing the electrical current through a contrivance known as a "spark coil" a certain change takes place in the electrical current and the voltage is increased. If the coil consists of a soft iron core with numerous coils of wire around it it is known as a *Primary Coil*, and is the kind used in the make-and-break system of ignition. If, however, the coil is composed of two different kinds of wire with the outer coil finer than the under and not connected with it, it is known as a *Secondary Coil*, such as is used in the jump-spark system.

Dynamos and magnetos are mechanical devices used to produce electricity, and a simple form of one of these is represented diagrammatically in Fig. 77. The pieces *A* and *B* are electro-magnets, or, in other words, are pieces of iron magnetized by means of a small current known as a *shunt S*, made to pass around them as shown. This shunt current is really a small part of the current produced by the dynamo itself. The ends of these two pieces of iron are known as *poles* and between them is a space known as the *magnetic field*. In this area an axis or *armature*, *C*, is rotated, upon which wires are wound so that the windings are continually passing through the lines of force between the poles and thus currents of electricity are generated in the wires. As the rotation of the armature causes currents in the wires which flow in opposite directions, these currents are gathered so *they will flow* in one direction through the outside wires where the current is to be used, and to accomplish this purpose small pieces of carbon or other substance known as *brushes*, *D*, are used which rub on small segments of copper known as a *commutator*, *E*, at-

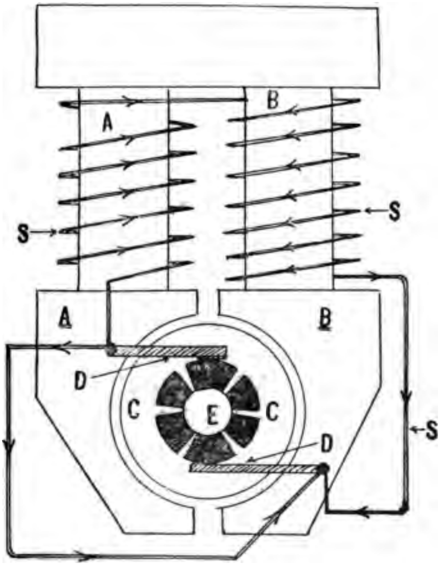


Fig. 77.—Diagram of Dynamo

tached to the end of the armature and to which are fastened the ends of the wires used in winding the armature. The brushes are so arranged that they touch the copper pieces connected with the proper wires so that a direct current will flow through the outside circuit.

In Fig. 78 is a diagrammatic section of a magneto. Here *A* and *B* are the magnets, but in this case they are permanent, or true, magnets and no shunt current is required; it is mainly in this detail that dynamos differ from magnetos. An electrical field exists between the poles or ends of these permanent magnets, and a revolving armature *C* with its windings cuts through the lines of force, producing currents in the wires exactly as in the dynamo. Brushes *D* and a commutator *E* are again used in this case to gather the flow of current in one direction. The strength of current generated by the above machines is dependent upon the size of wire, the *strength of the* magnetic field, the number of turns of

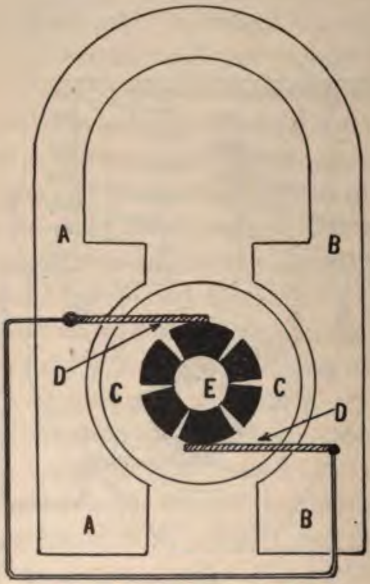


Fig. 78.—Diagram of Magneto

wire, and the speed at which the armature is rotated. For this reason the shunt current of the dynamo increases rapidly as the speed of the machine increases, thereby increasing the magnetism of the electro-magnets and the field so that the strength of current will increase more rapidly in this type with the speed at which it is operated than it will in a magneto with permanent magnets. To obviate this difficulty with the dynamo a governor is supplied which regulates the speed of the armature regardless of the speed of the engine to which the mechanism is attached. This governor is essential where a magneto or dynamo is to be used for ignition in order to prevent burning out the wires at high speed and yet produce a good spark at low engine speed. As a source of current either a dynamo or magneto may be used exactly as if it were a storage or dry battery, or it may be attached to a switchboard and used to accumulate electricity in a storage cell which can then be utilized for ignition and lighting.

Magnetos are divided into two general classes, high-tension and low-tension. The low-tension magneto consists of magnets as usual, but with a primary winding only, as in primary coils, and the current is broken at the instant of its greatest intensity. Other low-tension magnetos are fitted with timing devices by which the current can be broken and a spark produced when desired, thus allowing the spark to be retarded or advanced and thus regulating the time when ignition of the charge in the engine takes place.

High-tension magnetos have an armature provided with two windings like the jump-spark coils. These machines are fitted with a mechanical breaker which produces an induced effect on the secondary winding and therefore no spark coil is required. The Bosch, Simms, and various other magnetos are of this type. Another high-tension system consists in using a sort of low-tension magneto in which the current is passed through an induction coil fitted with a mechanical breaker. The Splitdorf, Holley, and Eiseman magnetos are of this type, while the Remy magneto has a stationary winding with two revolving inductors, thus eliminating revolving wires, brushes, and moving contacts. The great majority of magnetos in use, however, are of the low-tension type, and these possess the great advantage that their current can be passed through the regular spark coil and thus be switched off or on from the battery circuit at will. Moreover, these machines may be used with advantage for lighting purposes. The Eureka magneto manufactured by the Henricks Novelty Co. is of this type, and this wonderful little machine will ignite the motor charge and operate a total of 36 candle-power electric lights at the same time. This firm also manufactures a number of other magnetos, among them the "Comet," which is probably the smallest and most compact magneto made that is really practical. Many magnetos are inaccessible and are so complicated in construction that if out of order an electrical expert must be called on to adjust them. In the Comet the parts are very few and any one can take down, adjust, and repair one of these machines. The illustration (Fig. 79) shows the few parts and simple construction, while the brush holders can be removed without wrench or screw-driver, thus permitting examnation or cleaning at any time.

A unique variety of magneto which has recently been perfected is the "Wico Igniter" made by the Witherbee Ignition Co. In this machine there is no rotary motion, the electrical current being generated by reciprocating,

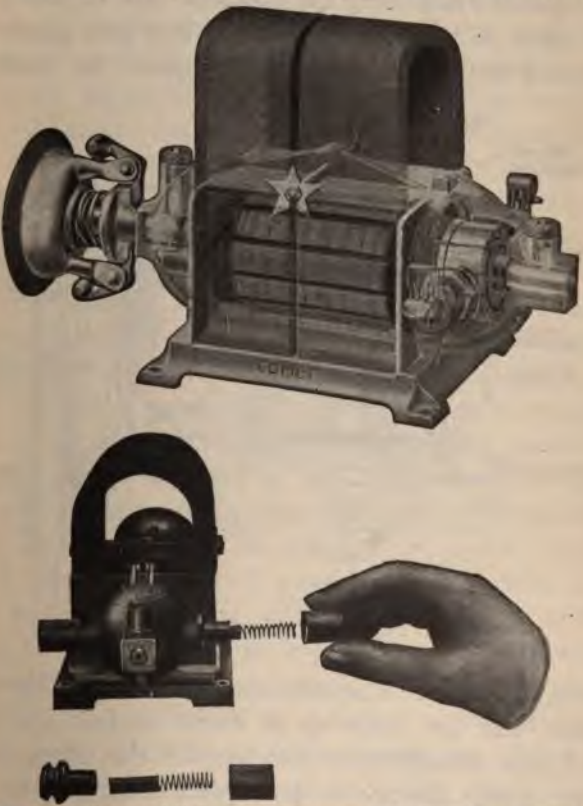


Fig. 79.—Parts of "Comet" Magneto showing Accessibility

or sliding, motion only. This remarkable machine is illustrated in Fig. 80. The magnets consist of tungsten steel permanently magnetized and fastened to cast-iron pole pieces which carry the magnetic lines of force from the poles to the soft iron cores. The pole pieces are fastened to the base casting and support the magnets' cores and coils. The cores fit into slots in the pole pieces and are built up of sheets of soft iron, and each core extends from just beneath the upper armature down through a pole piece and coil to just above the bottom armature. The armatures consist of sheets of soft iron mounted on a spool-shaped piece which in turn is loosely fitted onto the squared *end of the* armature bar. This armature bar is

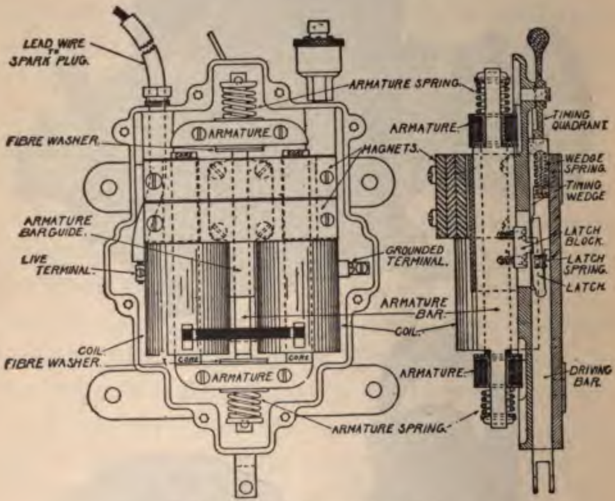


Fig. 80.—"Wico" Igniter

a piece of steel, its central cross-section being flat while its ends carry the armatures and are square. This leaves shoulders which bear against the armatures through the medium of fibre washers, the shoulders serving to carry the armatures in and out of contact with the cores when in operation. The armature itself is freely supported by a box-shaped guide which is fastened to the case. On the outer ends of the armature bar are spiral springs held in place by cup-shaped washers and pins, making a self-locking fastening similar to valve-spring fastenings. These springs bear against the armatures and force them against the shoulders of the armature bars. The coils each have a simple, high-tension winding and are connected by a metal strip, thus making a continuous winding. In the single-cylinder machine one end of the winding is grounded to the case of the igniter while the other end runs to the spark plug of the motor. In two-cylinder machines no ground connection is used, but both ends of the windings are connected to the plugs of the motor. In the back of the case there is a square slot in which slides the square driving bar. This bar receives its motion from the engine and at its upper end is provided with a pivoted latch of hardened steel. The latch is held in against the latch block by a spring which fits into a recess between the latch and the driving bar. Above the latch is a hardened steel timing wedge which is held upward against the timing quadrant by a spiral spring. The timing quadrant is pivoted on the back of the case and is moved by a small handle projecting above the case.

As the driving bar, connected with the engine, is moved upward carrying the latch with it, the shoulder on the side of the latch snaps under the square head of the latch block. As the motion reverses, the latch carries the latch block and armature bar upward. The lower armature being in contact with the stationary cores cannot rise with the bar, but the lower spring is compressed between the retaining washer and the armature while the bar rises and carries with it the upper armature which bears against the upper shoulders on the bar. As the driving bar continues its upward motion the bevelled upper end of the latch meets the lower end of the timing wedge, and as the wedge is stationary a further movement of the latch causes it to be pushed aside until its shoulder clears the latch block and releases it. As the lower armature spring is at this time exerting a pressure between the armature bar and the cores through the lower armature, the instant the latch is released the armature bar is pulled quickly downward carrying the upper armature with it. Just before the motion of the upper armature is stopped by hitting the cores, the lower shoulders on the armature bar come in contact with the lower armature and its momentum carries the lower armature away from the cores against the pressure of the upper spring which acts as a buffer.

The electrical action which ensues by this operation is as follows. With the parts in position as shown, the magnetic lines of force starting from one pole of the magnets flow through the adjacent pole piece to the core, downward through the portion of the core covered *by the coil* to the lower armature, across to the other core, and up to the other pole piece and other pole of the magnets, thus completing the magnetic circuit. The magnetic lines cannot travel upward and through the upper armature because it is separated from the cores by air gaps and the lower path offers less resistance. The portion of the cores covered by the coils is therefore magnetized, the same as in the core of a jump-spark coil. When the armature bar released from the latch is at the end of its downward stroke, the armatures occupy the opposite positions with relation to the cores —that is, the upper one is in contact while the lower one is separated. The magnetic circuit through the lower part of the cores is thus broken while the top forms a bridge for the magnetic lines across the tops of the cores. The combined action of the two armatures causes a very sudden demagnetization of the cores covered by the coils, which thus induces a wave of current in the coils, as is done in an ordinary induction coil when its core is demagnetized by breaking the primary circuit. In this igniter the permanent magnets replace the battery and primary winding, while the armatures replace the vibrator and timer in interrupting the magnetic flow through the cores. The timing of the spark is accomplished by releasing the armature bar earlier or later in the stroke. This is done by shifting the position of the timing quadrant which in turn varies the position of the wedge so that it releases the latch earlier or later. The timing quadrant is provided with several notches into one of which the top of the wedge fits, thus holding the quadrant in the desired position. At one end of the quadrant there is a notch considerably deeper than the others. This notch is so deep that when the wedge rests therein the latch is not tripped, and consequently the armature bar is not released and no spark is produced. In this position the quadrant acts as a switch and by mechanical means shuts off the current.

The advantages of this new form of igniter over rotating magnetos are numerous. It produces a hot spark at very high voltage for starting the engine, as the spark strength is entirely independent of the speed at which the engine is operated, and also because the voltage is strongest with the spark in its retarded or starting position. It is simple, strong, very compact, and dust-, oil-, and water-proof; moreover, it does away with all outside appliances and accessories such as switches, batteries, coils, wires, etc., the only wire exposed in the whole system being the short secondary wire leading from the igniter to the motor spark plug.

In using a jump-spark coil some method must be provided for interrupting or breaking the current in order to produce a spark in the induced current of the secondary winding. This is ordinarily accomplished by the use of what is known as a *Vibrator*. Fig. 81 represents a diagram of a jump-spark coil, and in this figure *A* is the core; *B*, the primary winding; *C*, the vibrator; *D*, the vibrator spring; *E*, the contact points; *F*, the adjusting screw; *G*, the condenser; *H*, the timer; and *I*, the secondary winding. As the core *A* is magnetized by the current passing around it in the primary winding *B*, the iron will, of course, be alternately magnetized and demagnetized as this current is made or *interrupted*. This intermittent magnetizing of the core is brought about by means of a timer, a mechanism on the engine which alternately connects and separates the points between which the primary current flows. This alternating magnetization and demagnetization of the core is used to operate the piece *C*, at the end of the spring *D*, in such a way that when the spring in its normal position is touching *E*, the current from the magneto or battery flows through the wire as shown by the arrows, thus magnetizing the core, but the instant the core becomes a magnet the piece *C* is drawn against its end, thus separating the spring *D* from the point *E* and breaking the primary circuit, causing the core to lose its magnetism and therefore allowing the piece *C* to spring back against *E*, again making the circuit, and thus operating over and over again as long as current is supplied to the primary winding. Non-vibrating coils

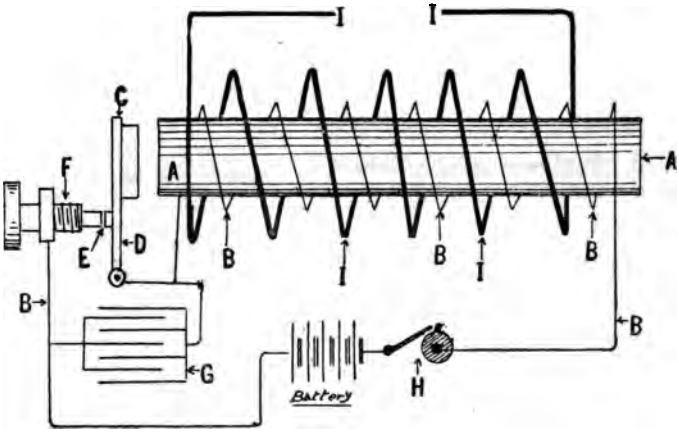
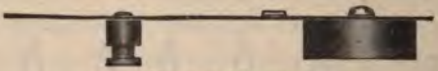
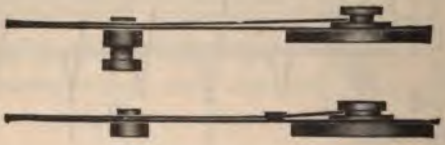


Fig. 81.—Diagram of Jump-spark Coil

are used on many engines, but in these coils only a single spark is produced each time the timer on the engine makes and breaks the primary circuit; and hence there is less likelihood of getting a powerful, hot spark than where the vibrating coil is used which produces a series of sparks at each contact of the timer points. The advantage of the non-vibrating coil lies in the fact that the vibrator, contact points, and adjustments are done away with, but as this type of coil does not "buzz" it is far more difficult to locate the trouble than with a vibrating coil in case of failure to "spark" properly.



Hammer Vibrator



Ribbon Vibrators

Fig. 82.—Types of Vibrators

An important part of the coil to consider is the vibrator itself, and upon the proper adjustment and construction of this depends in great measure the efficiency of the spark. Vibrators are made in various styles known as Hammer vibrators, Ribbon vibrators, Feather vibrators, etc. (Fig. 82), and the particular kind and make best suited to a particular motor can only be determined by experiment. As a rule slow-speed engines do best with a hammer vibrator, medium-speed motors with a ribbon vibrator, and high-speed motors with feather vibrators. A good coil, when properly adjusted, should consume about ¼ to ½ ampere for each cylinder. By adjusting the points nearer together or farther apart by means of the adjusting screw *F* (Fig. 81), the amount of current consumed may be increased or decreased and the spark made weaker or stronger. If the points are too close the current consumed will be greatly increased without increasing the operation of the engine and with injury to the coil. The aim should be to use just as little current as possible and obtain a good spark and proper ignition. The best way to accomplish this is to test the flow of current with an ammeter placed between the battery connection and the coil, and then adjust the coil until it consumes the minimum current without missing explosions of the motor. If this method is not available it is a good plan to gradually loosen the adjusting screw with motor running until the engine commences to miss explosions. As soon as this occurs turn the screw down very slowly until the engine runs regularly, and leave it in this position. When the coil is once properly adjusted it should never be changed unless the motor misses explosions or loses power and the trouble is located in the adjustment of the coil.

The sparking points on a coil will frequently burn or wear down until they are pitted, are uneven, or stick together and fail to vibrate. This may be remedied by carefully smoothing them off with a fine flat file, but a better plan is to occasionally change the wires from the batteries so that the current flows in the opposite direction and thus depolarizes the contact points. If your wires have been connected so that the carbon of the battery led to the coil and the zinc to the ground, shift them so that the zinc leads to the coil and carbon to the ground. An important part of all vibrator coils is the condenser (Fig. 81, *G*). This consists of layers of tin-foil separated by mica or paraffined paper. The sheets of foil are connected together alternately and these connections are then brought across the vibrator of the coil through proper wires. The condenser is usually placed in the bottom of the coil box, out of sight, and as the wires and connections are all inside there is no external evidence of the condenser and many users of coils are entirely ignorant of its existence. The function of the condenser is to reduce the spark at the primary break (at the vibrator points) which without it would be larger than that produced at the secondary terminals of the spark plug. This result is accomplished by the capacity of the condenser being just great enough to neutralize the self-inductance of the primary current by temporarily absorbing the impulse in the primary current at the moment it is broken by the vibrator. Almost instantly, however, there is a reverse action and the stored energy in the condenser flows back with extreme rapidity and adds its quota to produce a larger secondary spark. In the Orswell and Perfex systems of ignition the coil is located in a casing attached to the spark plug, while the vibrator and condenser are in a separate case or box near the batteries. This obviates long secondary wires where short-circuiting is most likely to occur, and produces a hotter and larger spark, owing to lack of resistance that will occur where long secondary wires are used. Similar results are obtained by the use of cylindrical water-proof coils with vibrator attached to the cylinder of engine near the plug, as used on the Gray motors, or by a form of coil attached to the plug itself, as used in the Solocoil and Caille Perfection systems. In either of these latter systems the coil does not differ materially from an ordinary vibrator coil, but the length of secondary wire is reduced to a minimum and as the switch is placed on the coil itself only two wires lead from the battery to the engine.

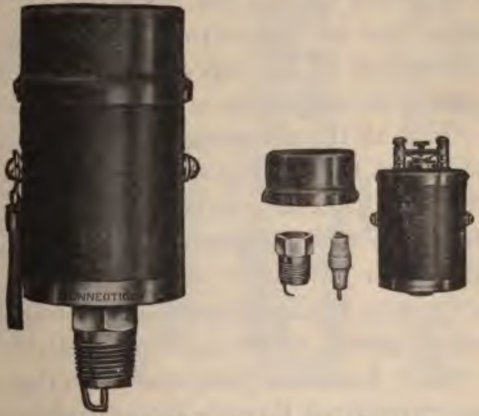


Fig. 83.—"Connecticut" Plug Coil

Another form of coil, manufactured by the Connecticut Telephone & Electric Co., which has recently been placed on the market, is designed to overcome all the usual troubles of the jump-spark system for marine work. This coil consists of a water-, heat-, and oil-proof casing attached directly to and covering the spark plug, thus entirely eliminating all secondary wiring and at the same time acting as a plug protector. Only two wires lead from the battery or magneto to the engine when this coil is used (Fig. 135) and no shock can be received when adjusting coil or plug. The case is covered with a tightly fitting metal cap that locks in place by bayonet locks, and the severest tests of this coil for injury by heat or water have failed to prevent its satisfactory action. The plug coil is illustrated in Fig. 83, and as will be seen the porcelains are readily removable and cost less than a common plug, while the position of the coil on the top of cylinder renders it very convenient for adjustment or examination. In fact this new coil has all the advantages and none of the disadvantages of the Perfex or Orswell systems. It is as secure from short-circuiting as these devices, and in addition does away with the separate vibrators and condensers with their attendant wiring. Several other manufacturers have recently placed similar coils on the market, but all operate on the same principle.

In the earlier forms of jump-spark ignition much trouble was encountered through short-circuiting, especially in the secondary current or spark plugs, and the use of the jump spark was largely confined to cabin boats and to stationary and vehicle use. With improved coils and magnetos, thoroughly insulated wire and timers, and highly developed spark plugs much of this difficulty has been overcome and little trouble is now encountered with short-circuiting, even in open boats. Usually the greatest trouble is in the spark plugs, and these simple and cheap accessories are often given far less attention than they deserve. There are a large number of makes of plugs on the market—some good, others better, and some very poor—and it will always pay to have the best and to keep several on hand for emergencies. The ordinary types of plugs are shown in Fig. 84, which illustrates the forms known as the "Petticoat" and "Conical" types, as well as the porcelains removed to show internal construction. These answer very well

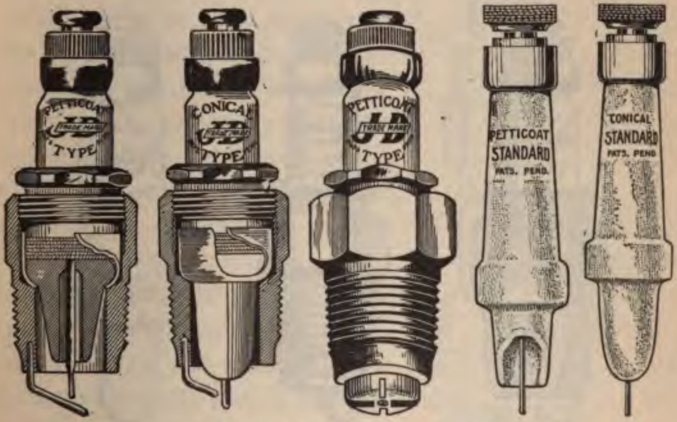


Fig. 84.—Types of Standard Plugs and Porcelains

for stationary or vehicle use, but where used in an open boat or under severe conditions of any sort a specially constructed plug should be used that will resist short-circuiting to the highest degree. Probably the nearest to a trouble-proof plug yet produced is the Reliance. This plug in its various forms is illustrated in Fig. 85. The porcelains are also shown removed, and the sectional view shows the internal construction. These plugs are provided with a very small platinum point embedded in the porcelain and ground flush with it. Above this and connecting it with the terminal at the top of plug is a copper quill and spring which compensates for any difference in expansion and contraction between the porcelain and metal and also prevents breakage of the porcelain by tightening too much on the packing nut. The fine platinum point concentrates and intensifies the spark to such an extent that the heat and scouring action instantly destroys any short-circuiting material around it on the surface of the porcelain. So efficient is this action that a Reliance plug will actually spark when immersed in a glass of water.

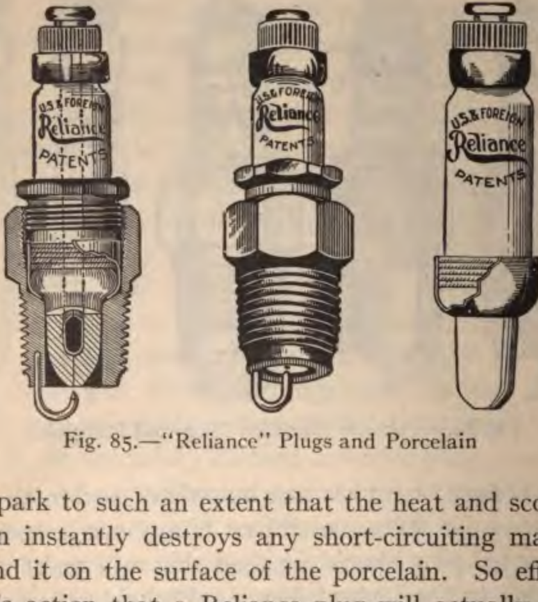


Fig. 85.—"Reliance" Plugs and Porcelain

Notwithstanding this high efficiency they will at times short-circuit when hot and suddenly drenched with spray or when thoroughly saturated with moisture after *being exposed* to rain or fog. By merely wiping off the outside of the porcelain and rubbing with oil or grease the trouble is readily overcome, however, and the spark plug will continue to operate as before. Probably no plug can be made that will not occasionally short-circuit under severe marine conditions, and the Reliance is certainly very near perfection. Many other excellent plugs are to be had and the choice lies mainly with the user; one person having far better results with one kind than another. The Wright, Spit-fire, Never-miss, Sta-rite, Sootless, Red-head, and many others are all good plugs and give highly satisfactory results Several makes are so constructed that they may be readily taken apart for examination or cleaning, and this is a most valuable feature where the plug is difficult to remove from the cylinder or is inaccessible. The Breech-block plug (Fig. 86) is constructed with the porcelain held in position by an interrupted screw which is turned by a lever and can be almost instantly opened and closed the same as the breech block of a modern cannon. The Rajah plugs illustrated in Fig. 87 are also readily taken apart and consist of but four pieces, all of which are interchangeable and easily removed or replaced. When using a high-tension magneto for ignition separate plugs must

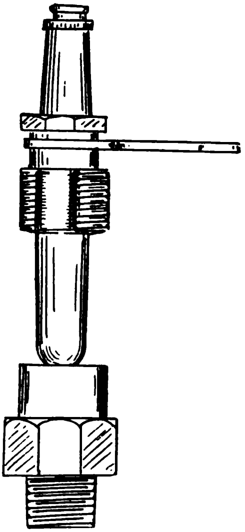


Fig. 86.—Breech-block Plug

be used for the battery and magneto, and this requires two plugs in the cylinder. Magneto plugs are especially constructed to withstand the high, hot current of the machine and are manufactured by almost all spark-plug makers. To obviate the use of two separate plugs combination plugs with two terminals—one for magneto and one for the battery—are furnished. These are known as the Edison type, and one of this kind as well as a standard magneto plug are shown in Fig. 89.

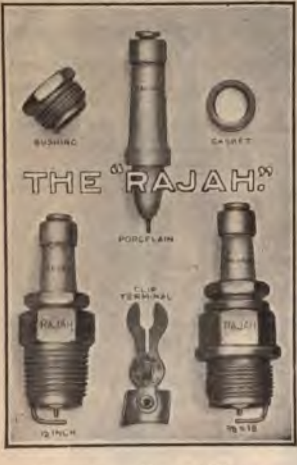


Fig. 87.—Rajah Plugs

A distinct advance in plug construction is found in the "E-Z" plugs illustrated in Fig. 88. These plugs can be instantly removed to clean the points or to replace porcelains without the use of any tools whatever. The lower portion of the plug screws into the cylinder as usual, while the upper portion, consisting of the electrodes and porcelain, slips into the lower shell and is fastened securely by a bayonet lock. Where plugs are frequently removed, or are difficult to get at with a wrench, this is a most excellent feature and cannot be too highly praised. The plug can also be used as a priming cap or relief cock, for the quarter turn required to open it is as easily made as turning on an ordinary cock. The *joints are held* by asbestos and are guaranteed against leakage; and a test by the writer failed to develop any leak under 350 lbs. air pressure.

Timers are of many kinds and vary from very simple affairs to highly finished and complicated devices, but the function of all is merely to interrupt and complete the current of the primary circuit in unison with the compression stroke of the motor, so that the explosion will take place at the proper instant.

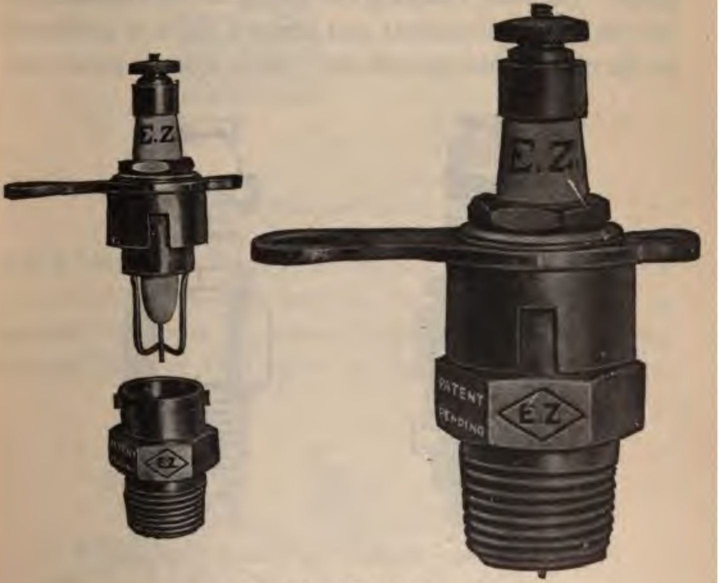


Fig. 88.—"E-Z" Plugs

The simplest form of timer consists of a spring and cam (Fig. 90). In this form of timer the ground wire is attached to the engine frame (*F*) and the other wire to the terminal *A*, on the spring *B*, which is insulated from the engine by the fibre block *C*. The cam *D* is fastened to the valve-gear shaft or to a special shaft operated by the motor and so placed that it will bear against the spring *B* at the instant when the explosion should take place. The cam, touching the spring, forms a connection for the electrical current and hence a spark is produced at the plug within the cylinder. As in order to secure the greatest efficiency from a gasolene motor it is necessary to explode the gas just before the piston reaches the uppermost limit of its stroke, some device must be provided to time the spark to take place at different points in the engine's revolutions. If the spark was advanced enough to give the best results when operating at high speed, it would ignite the charge too soon at low speed and when starting, thus causing pounding, *or backfiring,* with disastrous results to motor and oper-

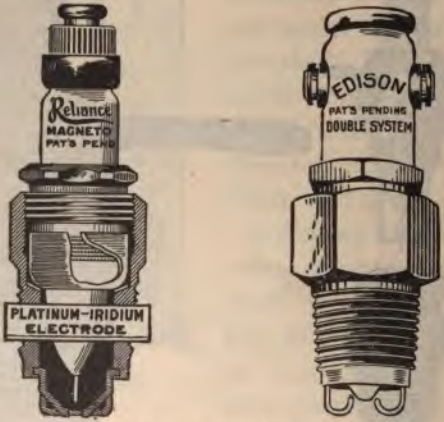


Fig. 89.—Magneto and Edison Plugs

ator. To accomplish this variation, a shifting device known as a *spark advance* is used. This consists in having the spring, or other arrangement, to which the insulated terminal is attached, mounted on a pivot

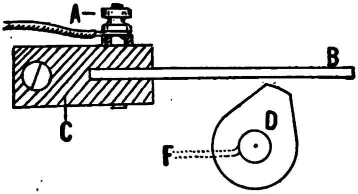


Fig. 90.—Cam and Spring Timer

which allows the timer to swing in a segment of a circle around the cam. By moving the timer backward or forward the spark is produced either before or after the upward limit of the piston on the compression stroke.

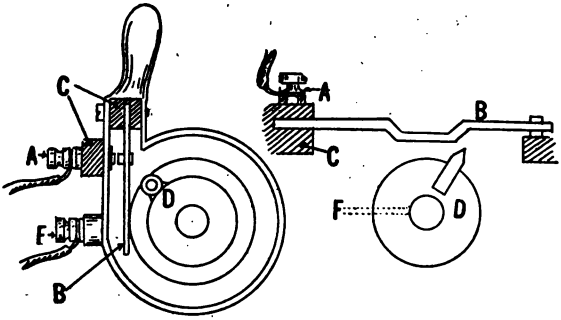


Fig. 91.—Simple Timers

The advance may be operated by a short handle or lever attached directly to it or may be operated from a distance through the medium of rods and levers as in the case of automobiles and other vehicles.

Other forms of simple timers are illustrated in Fig. 91, but in all of these the operation is so similar to the one described that a further explanation is not essential. These simple timers work very well for stationary engines and many of them are in use on automobiles and on marine engines. A peculiar but very satisfactory timer for marine engines is that used on the Tuttle motors and which is illustrated in Figs. 92 and 93. In this timer, *A* represents the eccentric on the engine shaft, which also operates the pump plunger *P*. The eccentric rod *B* is pivoted at the point *C* to the pump plunger, and the upper end is carried out and terminates in a holder *D* carrying a small electric brush, which is *backed by* a spiral spring shown in the section at *E*, *F*

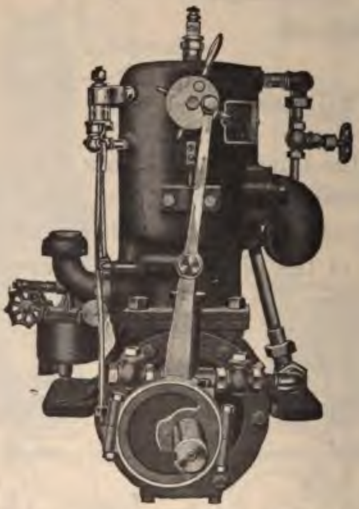


Fig. 92.—"Tuttle" Timer on Motor

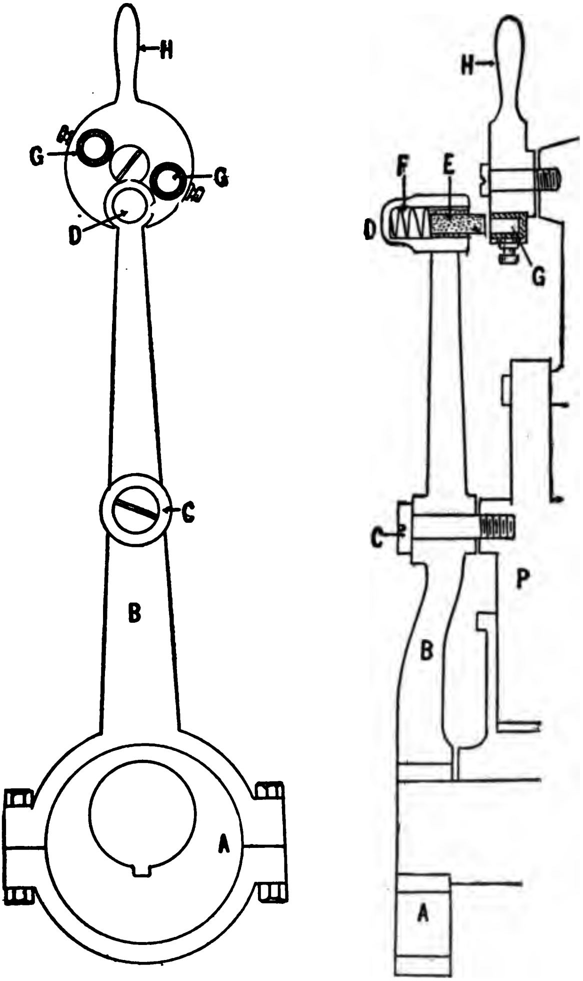


Fig. 93.—"Tuttle" Timing Device

Near the top of the cylinder of the motor there is placed a circular bronze disk, pivoted to the cylinder and provided with metallic inserts surrounded with insulating material ground flush with the surface *G*. The terminals from the wires are fastened to these insulated inserts and the ground wire attached as usual to the engine frame. In operation the eccentric rod bearing the brush which presses against the timer-disk by means of the spring *F*, revolves in a circle of the same circumference as the timer disk. As the brush passes over the insulated inserts an electrical connection is made and a spark produced, but while passing over the rest of the surface no spark is produced as this portion of the disk is thoroughly insulated from the terminals. By moving the disk backward or forward by the lever *H*, the spark is advanced or retarded.

The timers now generally used are enclosed in tight cylindrical cases and are operated by a timer shaft in the case of two-cycle motors (see Figs. 38 and 39, *S*) or are attached to the valve cam-shaft in four-cycle motors. They are of two general styles—roller contact and spring contact—and those two types are shown in Fig. 94. Their operation is so simple and so similar to those already described that no explanation is required, however.

Many more complicated forms of timers are in use, such as Monitors, Unisparkers, Distributors, etc., but these are generally used for special magnetos or dynamos or with certain kinds of engines or very highly developed and complicated motors for vehicle or racing use. Full explanations and directions for their use and operation are always furnished by the makers, and the amateur should never attempt to regulate or repair one of these delicate instruments. A very successful system is known as the Delco, in which one unit embodies a timer, a means for advancing and retarding the spark, and a high-tension distributor. This entire combination is known as the "Distributor" and requires but one coil for any number of cylinders. The distributor is rigidly mounted on the engine and does not rotate as does the ordinary timer. The spark control is effected by moving a lever on the side of the case, and this eliminates all

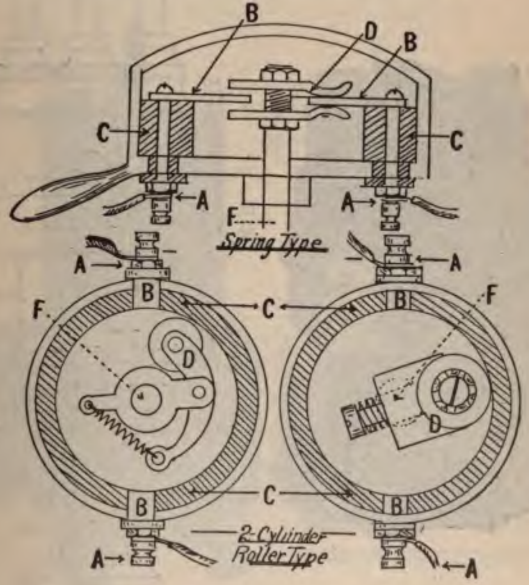


Fig. 94.—Roller and Spring Timers

moving wires and makes possible better mechanical construction. The distributor is illustrated in Fig. 95.

The distributor is used in connection with a coil, a relay, and a switch, and these are furnished either separately or combined within a common case or box. The relay is the apparatus for breaking the primary circuit and takes the place of vibrators on ordinary coils as it acts for each cylinder in turn as the com-

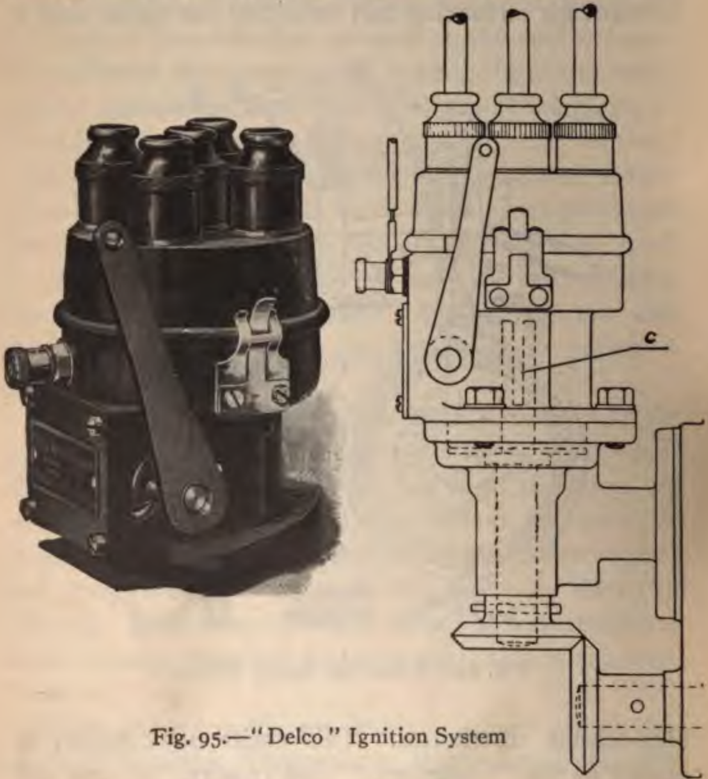


Fig. 95.—"Delco" Ignition System

mutator or timer makes connection. From the ordinary vibrator it differs, inasmuch as it uses but one spark for each contact instead of several. This relay is the only moving part of the entire system, and is very easily adjusted or regulated. This Delco system has been adopted with great success by many motor-manufacturers, and is used on many of the leading automobiles. As a rule, however, the simpler and more accessible the timer and ignition system the better, for nine-tenths of motor troubles are due to faulty ignition and the simpler the entire electrical system is made the more readily can the operator locate his troubles. Small, delicate, or

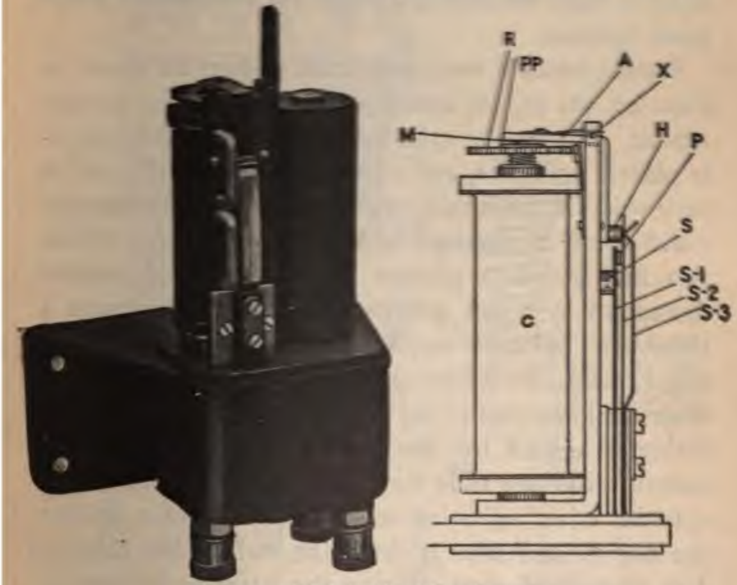


Fig. 95.—"Delco" Ignition System.

intricate parts should be avoided, and in this respect the jump-spark system far excels the make-and-break. In the latter system of ignition a simple primary coil is used and no vibrator or timer is required. This greatly simplifies the electrical apparatus, but the number of small parts, springs, etc., used in the igniter render it liable to many troubles absolutely unknown to the jump-spark ignition.

Several forms of make-and-break igniters are shown in Figs. 40, 96, 97, 98, and in each the operation is very similar. Within the cylinder a stationary electrode *A* is placed, to which one of the wires from the coil is fastened. On the outside of the cylinder there is attached a sliding rod *M*, operated by the eccentric rod *C*. Above this slide rod is a plunger *H*, which is held pressed downward by a stiff spiral spring *J*, bearing against a thimble *I*. Within a recess in the slide rod is an angular dog *F*, held forward by the spring *L*, and which bears upon the lower end of the thimble *I* or plunger *H*, thus lifting it against the force of the spring *J* when the eccentric rod and slide move upward. Fastened to the cylinder is an adjusting screw *G* which bears against the dog *F*, and trips it from the end of the thimble *I* or plunger *H*, thus allowing the latter to be forcibly driven downward by the action of the spring *J*. Between the top of the slide bar *M* and the thimble *I* a rocker arm *C* is placed, which is connected to a spindle *D*, bearing on its inner end within the cylinder a movable electrode *B*. When the slide moves upward, bearing the dog and plunger with it, the rocker arm is forced up to follow the spindle by the spring *K*, thus bringing the movable electrode *B* into contact with the permanent electrode or spark plug *A*, and completing the electrical circuit. As the slide bar reaches its upward limit the screw *G* trips the dog from the plunger, and the latter on its downward travel brings the thimble against the rocker arm *C* and thus snaps the movable electrode *B*

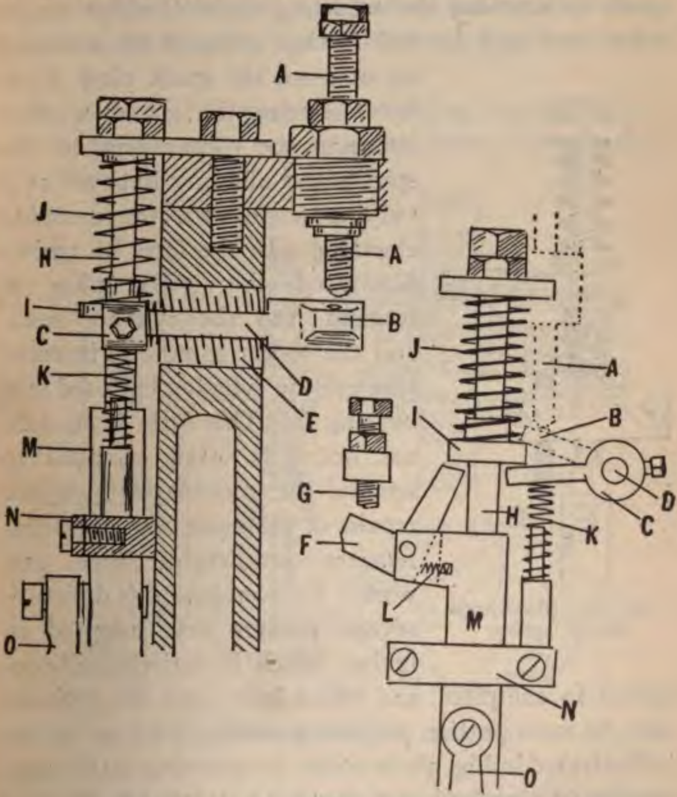


Fig. 96.—Make-and-break Igniter (Operation)

from the spark plug *A*, creating a sudden, hot k between the two.

he igniter may be timed to advance or retard the rk by screwing the adjusting screw *G* either up or wn, and may be still further adjusted by screwing up or down the spark plug *A*, or by loosening the set-screw that connects the rocker arm to the spindle and allowing it to set at a varying angle with the movable electrode. In the form of igniter illustrated the spark plug is screwed into the cylinder head, and the rocker spindle is inserted through the cylinder, enclosed in a bushing *E*. This form is in wide use, but it is often essential to remove the rocker electrode for repairs or cleansing and to do this requires considerable time and work. To overcome this difficulty several makers have adopted an igniter which is entirely self-contained in one piece, and which bolts onto the cylinder with its inner portion projecting inside. Such an igniter is illustrated in Fig. 98, in which the lettering is the same as already described and identical with that in Fig. 40.

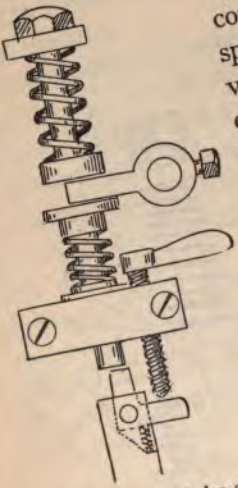


Fig. 97.—Make-and-break Igniter

The make-and-break system has the advantage of bein practically water-proof, for it is operated by a low tension current and is free from short-circuiting trouble For this reason it is a great favorite with fisherm

termen, and other users of open boats; but its dis-
antages in my mind more than offset its good points.
sparking points of the two electrodes frequently
ome foul with dirt or soot and the low-tension spark
ot sufficiently hot to burn this off as in the jump-spark
g.

he continual banging or hammering together of the
electrodes soon wears away the points, necessitating

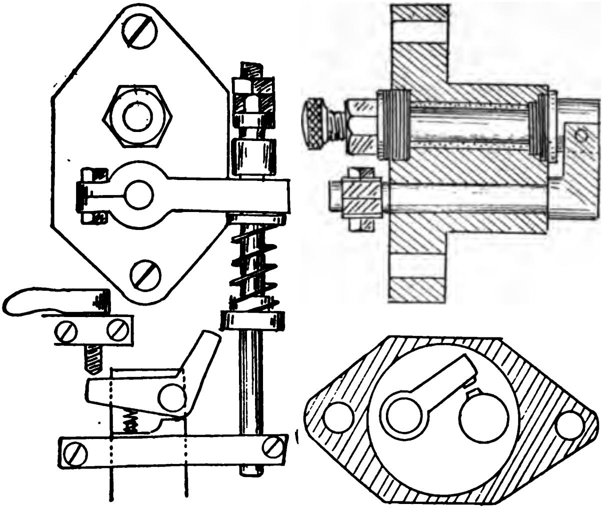


Fig. 98.—Self-contained Igniter

quent renewal and adjustment; the spindle of the
ker arm often becomes gummed or stuck with oil
rust, causing missfires or breaking of the spindle or
ker; the set-screw holding the rocker to the spindle
en breaks or wears loose, allowing the rocker to work

on the spindle without operating the interior electrode; springs lose their strength or break; and the mica insulation of the spark plug often breaks, or becomes so filled with oil and soot that it fails to act as an insulation. In addition to all these defects the make-and-break system is very noisy and dirty and requires constant care and attention. Many make-and-break

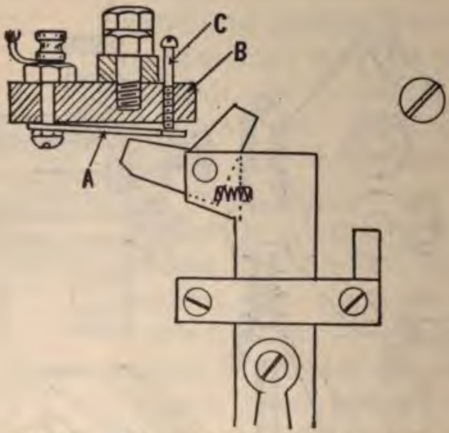


Fig. 99.—Make-and-break Igniter Altered to Jump-spark

motors that are practically worn out may be given new lease of life by converting them into jump-sp motors. This is usually very easy and inexpens If the igniter is of the external type illustrated in 40, 96, and 97, it is only necessary to remove the r and spindle and plug the hole; remove the plu plunger spring, thimble, and rocker spring. Fas piece of fibre—to which a terminal and spring is at —to the slide guide and replace the make-and

ug with a standard jump-spark plug. This trans-
rmed igniter is shown complete in Fig. 99. The dog
the slide bar coming into contact with the spring *A*
akes the electrical connection and causes a spark in
e cylinder. By placing an adjusting screw through
e fibre block *B*, as shown in *C*, the spring may be
essed up or down at will, thus retarding or advancing
e spark. In the case of motors having a rotary pump,
provided with a self-contained igniter, it is often
sier to attach a regular timer to the pump shaft or to
special shaft operated by gears on the engine crank
aft. Of course in any case where the system is changed
om the make-and-break to the jump-spark it is
cessary to substitute a vibrator coil for the primary
il used in the old make-and-break arrangement.

CHAPTER VII

MUFFLERS AND EXHAUST DEVICES—GOVERNORS—FUEL AND FUEL CONSUMPTION—OILS AND GREASES—INSTALLATION—PIPING AND WIRING—GASKETS AND PACKINGS—ADJUSTMENTS—GENERAL CARE OF MOTORS.

A VERY important part of a gasolene motor is the exhaust. As the burnt gases leave the cylinder at a speed of from 6,000 to 12,000 ft. per minute with a pressure of from 25 to 35 lbs. per square inch, it will be seen that it is of the utmost importance that the exhaust opening is of ample size to allow the gases to escape without creating a back pressure in the cylinder. In four-cycle motors the exhaust valve should also be large enough, and with sufficient lift, to allow the gases to escape quickly and completely during the scavenging stroke. If the exhaust gases were allowed to escape freely into the air there would be little danger of back pressure in the cylinder, but the speed and pressure of the gas would cause loud explosive noises and considerable flame; to overcome the disagreeable noise various devices are used, known as "silencers" or "mufflers." Mufflers and silencing devices are of a great variety of designs and construction, but the object in all is to overcome the noise to the greatest possible extent without creating back pressure. If the exhaust can be quickly cooled after leaving the cylinder, or if the gas can be allowed to fully expand before reaching the air, very little noise will result.

Many motors intended for marine use have an auxiliary exhaust chamber as an integral portion of the engine. In the Gray motors this chamber is merely an enlargement of the exhaust opening, but being water-cooled it serves to allow the gases to expand in addition to cooling them, thus materially reducing their pressure (Fig. 100). In other engines the auxiliary exhaust is in the form of a separate chamber or box attached to the cylinder by bolts and is either water-jacketed or arranged with a valve that allows a certain amount of the circulating water to pass directly into the exhaust gases. Such an auxiliary exhaust chamber is illustrated in Fig. 101.

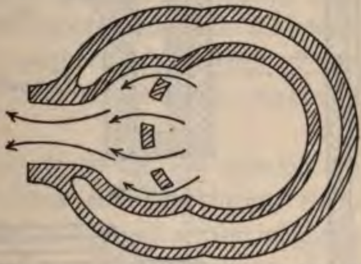


Fig. 100.—"Gray" Auxiliary Exhaust

On marine engines, it is customary to lead all or a portion of the circulation water into the exhaust pipe or muffler and thus cool the gas and reduce the pressure. In the case of vehicle or stationary engines this cannot be done to advantage, as the water used for cooling is generally confined to a definite amount which passes through a radiator or cooling device and is used over and over again. In air-cooled motors there is of course no method of passing water into the exhaust. If the exhaust is merely led into a large cylinder or chamber before reaching the air, the gases will expand and will pass out with but little noise. For stationary use such expansion-chambers, if of ample size, will usually prove efficient as a silencing device, an old cask or barrel, or even an inverted box, often being all that is required with small motors. In the case of large motors a cement or brick chamber is often used, and this can easily be

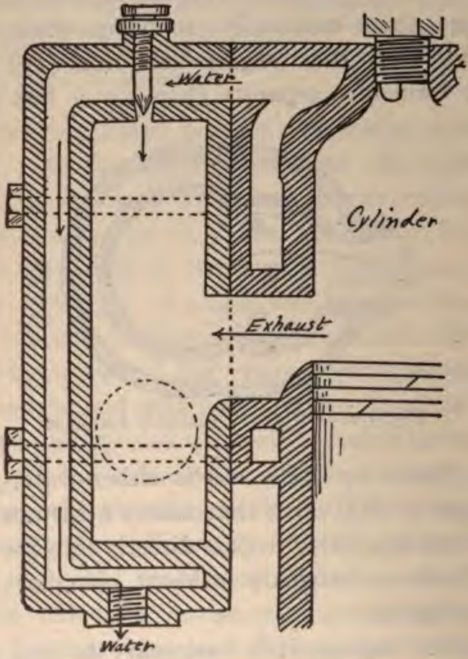


Fig. 101.—Auxiliary Exhaust

made large enough to permit full expansion of the gases and practically eliminate the sound of the explosions. In marine service there is often an under-water opening to the exhaust, but before leading the exhaust outboard an expansion chamber of ample size must be connected with the engine. With two-cycle motors there are many objections to the use of an under-water exhaust. The exhaust port being open during a considerable portion of the operation of the motor, combined with the fact that the explosive impulse and the inrushing fresh charge are the only methods of carrying off the burnt gases, often results in water or steam working back into the cylinder.

In a four-cycle motor the exhaust valve is closed against any back pressure during the entire intake stroke, and the burnt gases are forced out by the pressure of the piston during the scavenging stroke. For these reasons there is little chance of water or steam getting into the firing chamber. Wherever an under-water exhaust of any kind is used, however, it should be provided with a relief cock at its highest point of piping, as well as a drain cock at its lowest point; and it is also good practice to provide a three-way cock or valve at some point of the pipe in order that the exhaust may be turned off from its under-water connections and deflected through an exhaust pipe leading to the air above the water line. The valve connecting the under-water exhaust should always be turned off when the engine is to be idle for any length of time, for no matter how carefully the exhaust is installed or how far above the water line the motor may be, there is always a chance that the boat may fill through a leak in the piping or that it may leak sufficiently or be filled with rain to such an extent that the inside connections will be lower

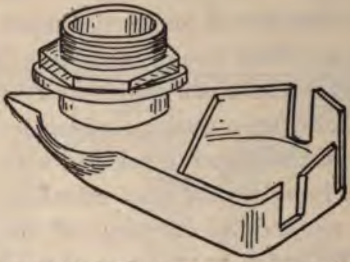


Fig. 102.—"Reid" Underwater Exhaust

than the water line, thus allowing the boat to fill and sink. The relief valve should always be opened when starting the motor to avoid the possibility of steam or water working back into the cylinder, and this valve should always be kept open when the motor is not in use.

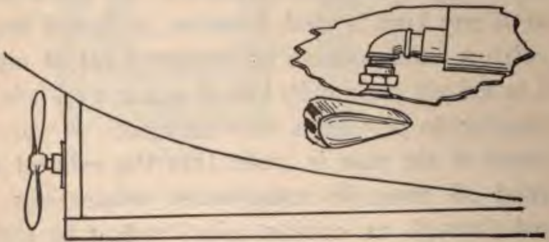


Fig. 103.—Exhaust on Boat

The drain cock at the lowest point in the pipe will serve to drain off any water in the pipe in cold weather and also in starting, for if a pocket of water collects in the pipe it will often draw back into the motor when first cranking it to start.

Until a motor gets well under way it is often very difficult to get good results with an under-water exhaust, and in such cases the three-way valve will prove very convenient, for by its use the exhaust can be deflected into the air until well started, when it can be turned into the under-water connections.

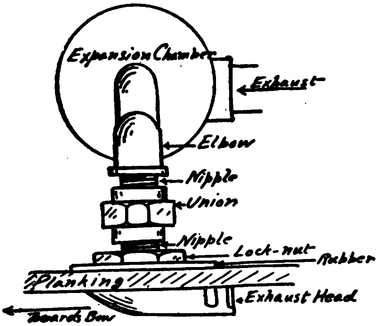


Fig. 104.—Underwater Exhaust Connections

Various methods of leading the under-water exhaust out from the bottom of the boat are in use, but the best method is to use an under-water exhaust head of some sort. A very good form known as the Reid is shown in Fig. 102. This is fastened to the side or bottom of the boat and connected with the exhaust pipe as illustrated in Fig. 103, a thin piece of rubber being placed between the planking and the head to make a water-tight joint. The arrangement of expansion chamber, exhaust pipe, three-way, relief, and drain cocks, and outboard head are shown in Figs. 104 and 105. In place of cooling or expanding the exhaust gases in order to reduce the noise a system may be used by which the rapidly moving volume of gas is broken up into innumerable small jets before reaching the air or by so retarding a portion of the gas that the exhaust reaches the air in a continuous or nearly uniform stream or jet. The fact that a steady stream of exhaust gas makes less noise and commotion than alternating jets renders the exhaust of a multiple-cylinder motor far easier to silence than that from a single-cylinder engine. In order to break up the volume of exhaust gases various devices are used. In the older forms of mufflers the exhaust was led into a chamber or casing filled with stones, pebbles, or coke (Fig. 106) which served to break up the gas into many small jets before it reached the air. Another form, shown in

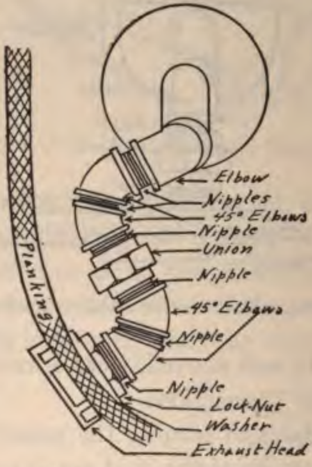


Fig. 105.—Underwater Exhaust Connections

Fig. 107, consists in a casing and a perforated pipe leading from the exhaust port of the engine. The gas, leaving this pipe through the numerous small holes, loses much of its pressure and speed and divides into many jets. As some of these are far nearer the opening to the air than others, the gases finally leave the silencer in a more or less continuous stream. If a second pipe of larger diameter is placed in the muffler, as illustrated in Fig. 108, still better results are obtained. Such mufflers are used considerably, but usually are rather inefficient and often create considerable back pressure.

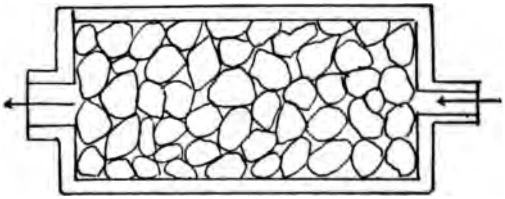


Fig. 106.—Muffler with Pebbles

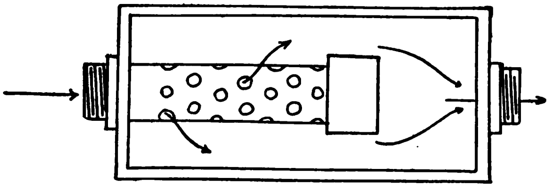


Fig. 107.—Muffler with Perforated Inlet

Other forms of silencers consist of hollow chambers provided with segments or plates perforated by small holes and set alternately in the chamber. This style of muffler is shown in Fig. 109, and if properly designed and of ample volume is quite effectual and creates little back pressure.

The well-known Yankee mufflers are constructed with a combination of these two systems. Sectional views are shown in Figs. 110 and 111. The gases entering at *A* partly pass through the perforations at *B* and are partly deflected by the partition *C* and the interior of the pipe *D*, and then expand in the chamber *E*. From this chamber they pass through the opening in the plate at *F* and hence through perforations in the outlet pipe at *G* and into the air through the tail piece *H*. In the Ejector muffler a very different system is used. This is illustrated in Fig. 112. It consists of three expansion chambers, *A, B, C,* which are separated by conical plates, *D, E, F,* *perforated* at top and bottom and arranged in two sets.

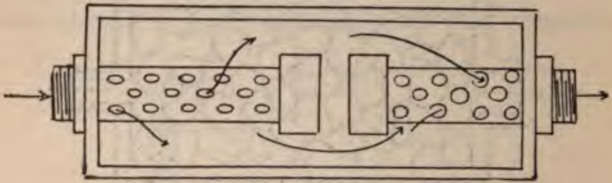


Fig. 108.—Muffler with Perforated Pipes

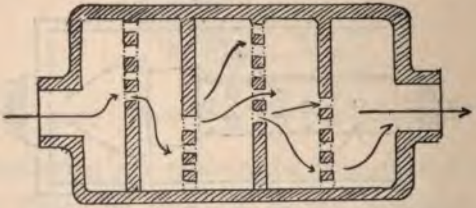


Fig. 109.—Baffle-plate Muffler

The central tube *G*, leading through the muffler, is of varying diameter and a portion of the gases from the exhaust passes directly into the central chamber *B* and hence through the second set of cones *D*, *E*, *F* (2), before the gas which enters the first chamber *A* has passed through the first series of cones *D*, *E*, *F* (1). A small portion of the gas is also led straight through the central pipe *G* to the outlet at a very high velocity. This creates a partial vacuum in the third chamber *C*, and the gas moves rapidly from the second chamber *B* to fill the partial vacuum in the chamber *C*. The forward movement of the gas through the first and second chambers *A*, *B*, to the third *C*, causes a sudden expansion which removes the heat from the gases and reduces the

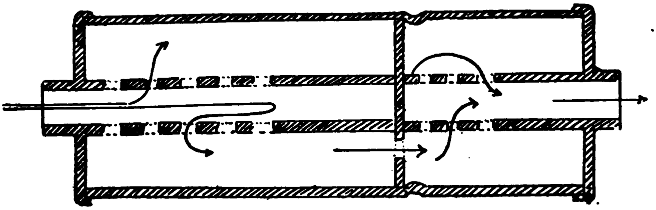


Fig. 110.—"Yankee" Auto Muffler

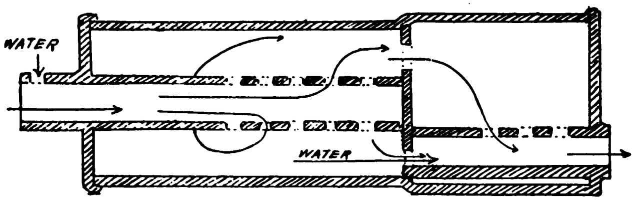


Fig. 111.—"Yankee" Marine Muffler

pressure in the muffler to below that of the atmosphere, thus allowing the gases to escape with no appreciable noise and no back pressure. These mufflers work excellently both in vehicle, stationary, and marine use; and in the latter case still better results are obtained by running a portion of the circulation water into the exhaust before it enters the muffler.

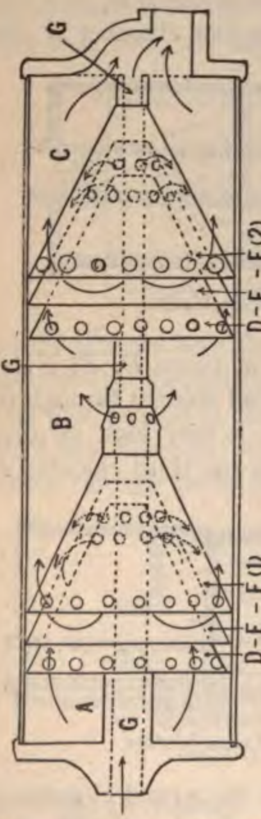


Fig. 112.—"Ejector" Muffler

In the Hydrex silencer, which is intended for marine use, and which is shown in Fig. 113, deflecting plates with small openings, an expansion chamber, and a water-cooling system are combined. The gases from the motor enter the silencer at *A* and are deflected upward and given a whirling motion by the internal cone. Water from the jacket enters at *B*, through an annular opening which forms a circular sheet of water, into the tube or inverted cone *V*. The gases deflected upward by the outside of this tube pass through this sheet of water *and are again* deflected down through the inner tube by the lips *C*, into the chamber *E*. The hot gases striking the water instantly lose their heat and pressure and noise, so that the cooled gases then issue quietly from the chamber by the outlet *G*. Any excess of water is provided for by a drain cock *B* at bottom of silencer, which leads directly to the bottom of the boat. The Thermex silencer works in a similar manner and is illustrated in Fig. 114.

Various other forms of excellent mufflers are in use, and new ones are constantly being designed and put on the market. Mufflers in which the gases are given a rotary or whirling motion are quite satisfactory; and silencers have been used in which the gases were led into a casing surrounding the fly-wheel which, being provided with fans or blades, acted as a blower. Whatever style of muffler, silencer, or expansion chamber is used, care should be taken to have the same of ample size to accommodate the exhaust gases without back pressure. A volume of 3½ times the square of the piston diameter times the stroke will usually be large enough, but even under the best conditions the perforations or other openings in a muffler will frequently become clogged with soot or rust and the silencing device and exhaust pipes should be frequently examined and cleaned, especially if an excess of oil is used.

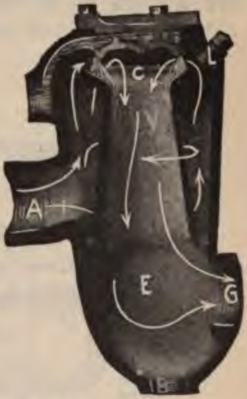


Fig. 113.—"Hydrex" Silencer

Whenever a motor is used under conditions of varying load or work, some method must be used to prevent the engine from racing or speeding up when running free and at the same time allow it to operate at its maximum speed and power when working. Such devices are known as governors, and are used principally on stationary motors. Many large marine motors as well as numerous vehicle motors also use governors, and their use adds much to the life and efficiency of any motor of considerable size and power. There are various methods of governing, the principal kinds being Hit-or-miss, Throttling, and Varying Ignition. In the hit-or-miss the action of the governor is to shut off the fuel supply, open or close the exhaust valve, shut off ignition, or disengage the valve mechanism. In the throttling method the fuel supply is reduced or the explosive gas throttled. In the varying-ignition system the governing is accom-

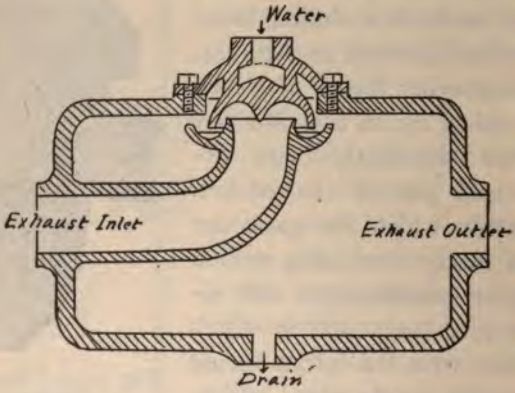


Fig. 114.—"Thermex" Silencer

plished by cutting off the current from the sparking device or by varying or timing the point of ignition. In Fig. 115 is illustrated a form of governor which operates by preventing the exhaust valve from opening. When the speed of the engine exceeds its normal limit, the balls *A* move outward, causing the cam *B* to be moved to the right by the action of the dogs *C* on the governor arms *D*, which are held in a grooved collar *E* on the sleeve *F*. The end of the cam *B* is thus prevented from acting on the roller *G*, until the motor falls to its normal speed, thus preventing the valve mechanism from operating the valve. Ordinarily the cam is held in position by the springs fastened to the governor balls, which hold the cam against the shoulder of the bearing *I* of the cam shaft *J*.

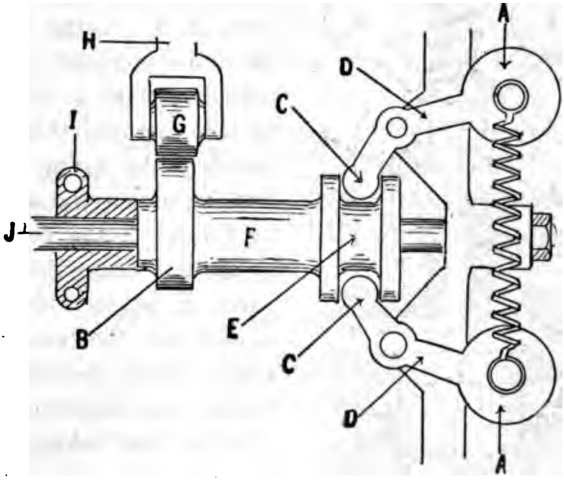


Fig. 115.—Exhaust Valve Governor

Another form of governor, shown in Fig. 116, may be used in connection with any of the governing methods mentioned, but is particularly adapted to throttling methods. The two balls *A*, *A* are rotated through any convenient method of connection with the motor, and in the illustration are represented connected by bevel gears *B*, *B*. As the speed of the motor increases the balls swing outward as indicated by the arrows, thus compressing the spring *C*, and pushing down the stem *D*, by means of the collar *E*; as the rod moves down, the valve *F*, at its lower end, moves past the holes *G*, *H*, which admit the charge of vapor, and thus gradually throttles the charge that passes to the engine through *H*.

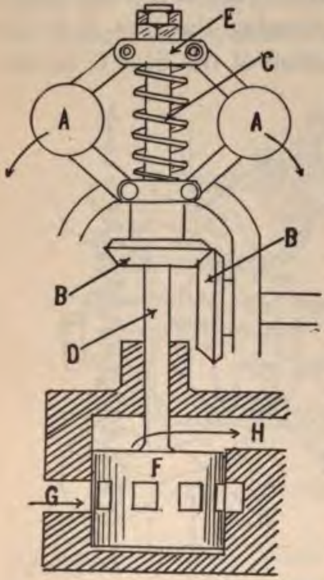


Fig. 116.—Throttling Governor

In Fig. 117 is shown a governor which operates on the hit-or-miss principle. When the motor races or runs beyond the normal speed the action of the balls causes the blade *A* to move away from the notched valve lifter *B*, thus throwing the valve out of action. A governor of the inertia type is illustrated in Fig. 118. In this form, if the engine attempts to run above normal speed, the lower end of the double lever *A* will be depressed by the cam *B*, and the valve lift *C* will be thrown out of engagement with the shoulder *D*, thus preventing any action of the valve until the motor speed drops to normal. Various other forms of governors are in use and these may be attached to a bracket fastened to the engine frame or may be bolted to the fly-wheel or cam shaft. In the Twentieth Century motors a centrifugal governor is fastened to the fly-wheel and through properly adjusted springs and rods is connected with the carburetor throttle. Governors are usually properly adjusted to give the best results when the motors leave the makers; and unless they become loose, broken or worn, or very evidently out of adjustment they should not be meddled with. As most governors depend to a large extent upon spring action, any rust, corrosion, or dirt on the latter is liable to affect the operation of the governor, and care should be taken that they are kept free from dirt and rust. They should also be frequently lubricated, but good machine oil and not cylinder oil should be used for this purpose.

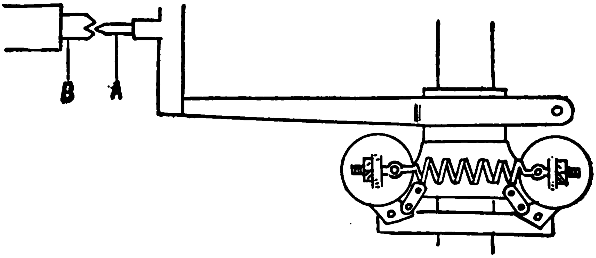


Fig. 117.—Hit-or-miss Governor

Various fuels are used in operating internal-combustion engines and practically any grade of gasolene, benzine, or naphtha may be used to operate a gasolene motor with slight variations in carburetor adjustments. Poor, stale, or dirty gasolene will often give poor results, and as a rule the lower grades are not so economical as the better grades. Moreover, poor fuel results in an excess of carbon and soot and should be avoided as far as possible. Many gasolene motors will run very well on denatured alcohol or kerosene if first started with gasolene. There is really but little reason for using these as fuel, however, for gasolene gives so much better results and so much less soot and carbon that it more than makes up for the additional first cost. Sometimes, however, the operator of a motor will find himself short

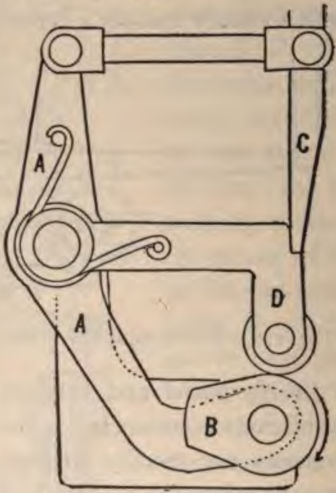


Fig. 118.—Inertia Governor

of fuel where no gasolene can be purchased. At such times, if the motor is started and well heated on gasolene, kerosene or alcohol may be used. It is always a good plan to carry a small quantity of your regular gasolene for use in an emergency, and this should never be used until absolutely necessary. The fuel consumption of a gasolene motor depends a great deal upon the care with which the carburetor is adjusted in order to use the minimum amount of fuel to obtain the best results; the accurate timing of valves and ignition, and the original design and construction of the motor. A two-cycle motor will use more fuel than a four-cycle, and a multiple-cylinder motor will use more than the same number of separate cylinders. Another item which enters quite largely into fuel consumption is the temperature of the cylinder. The best results are obtained when the temperature of the water in the jacket is kept at about 160 degrees Fahrenheit. With this temperature, high-grade fuel, and careful operation the average engine will consume about 1 1/5 pints of gasolene, or about 15 ft. of natural gas, per horse-power per hour under full load. Engines that will burn gas satisfactorily will usually burn gasolene, and *vice versa*, but it is best to have the motor arranged to consume a certain kind and quality of fuel. Many manufacturers provide devices for using kerosene in gasolene motors; and if kerosene is to be used it is far better to use such a device, or else purchase a regular oil engine, than to try to operate a motor intended for gasolene or gas by crude oil or kerosene.

Many operators of gasolene engines give very little care to the oil and grease used as lubricants. This is in reality a very important matter and too much care cannot be used in selecting the best oil for the motor and, when once found, adhering to one brand and not continually changing. Some engines require a much heavier oil than others and a new motor will usually work better on a light oil than an old or worn engine. In hot weather, also, a heavier oil can be used than in cold weather, for even the best of gasolene-engine cylinder oils will thicken up in cold weather. Many motors in which the rings or cylinder are so badly worn as to lose compression will operate very successfully if fed a heavier grade of oil, and in two-cycle motors a good supply of heavy oil or grease on the bearings results in better base compression and more efficient service. Machine oil or steam-engine oils should never be used in a gas-engine cylinder. The terrific heat in these motors will ignite any but oils made especially for the purpose, and poor or low-grade oils will form excessive carbon deposits. Oil is cheaper than motors and the very best on the market is none too good for the poorest motor built. Machine oil is very good for exterior use and for that purpose is superior to cylinder oil, but even where so used it should be of a high grade that will not gum or stick.

Greases used in grease cups and transmissions should be selected with as much care as the oil, for a poor grease will gum and stick, while a grease containing any grit, dirt, or foreign matter will soon cut out and ruin bearings. Some greases on the market are more like soft soap than grease; they are stringy, sticky, elastic compounds and are unfit for any use. A good grease should be smooth, clear-colored, clean and soft in any weather. The hardness or softness of a grease used should be determined by trial, and any reputable manufacturer of oils and greases will gladly furnish samples of the various grades. The grease used should be heavy enough so that it will not run and spread, and should be soft enough to feed easily and regularly through the grease cups. The oil used should always be strained before being placed in the lubricators, and if at any time the oil is found to contain any trace of grit or dirt it should be at once discarded and all oilers, oil-pipes, and bearings thoroughly cleaned with kerosene and gasolene before using new oil. The amount of oil to be fed to any motor, or to any part of a motor, depends largely upon the make, the age, the care, and the work of the engine as well as upon the grade of the oil. A new engine should be given a liberal supply of oil until well broken in, when the supply can be cut down somewhat. Too much oil will cause soot and carbon, but too little will result in wear and cutting, and of the two evils it is far better to use too much than too little.

When stopping the motor the oil should always be turned off, as otherwise an excess may get into the cylinder. If a mechanical force-feed oiler is used it will take care of itself in this matter. An excess of oil is readily determined by smoke from the exhaust, and a smell of burning or hot oil. If the proper amount of oil and a correct mixture of fuel are being used, the exhaust will be almost colorless or of a faint bluish tint. If too much oil is used the blue will increase until a dense bluish or yellowish smoke issues from the exhaust. If the mixture of air and fuel is too rich—that is, contains too much gasolene—the exhaust smoke will be either black or dense and white with a sharp, choking, pungent odor.

Most engine-makers furnish directions as to the proper amount of oil to be fed the various parts, and these should always be observed. Few moving parts of a motor require less than six drops per minute and few need more than fifteen or twenty, but in winter the adjustment of the lubricators must be altered to suit weather conditions in order to supply the proper amount of oil.

The installation of a gasolene motor seems a very easy matter, but really many excellent engines fail to give proper service or satisfaction owing to careless or improper installation. In vehicle motors this fault is not common, as the makers of motor-propelled vehicles install the motors themselves and usually see that it is properly done. Stationary motors that are manufactured mounted on trucks, frames, or skids are also usually free from faulty installation, but stationary motors set up by the purchaser and especially marine motors, are often so badly installed that it is surprising that they work at all.

The first consideration in installing a motor is the bed. For stationary engines the character and material of the beds depend largely upon the space available, the material at hand, and the location. Brick, stone, cement, and timbers all make good beds, but perhaps the most satisfactory method is to make a good solid *bed of concrete* in which timbers should be embedded just far enough apart so that the bed-plate of the motor may be bolted to them. The timbers should be of ample size, and, to hold them firmly in the cement or concrete, spikes or bolts should be driven into them at intervals before burying in the cement. The cement bed, as well as timbers, should be smooth and level, but a space under and around the motor may be made depressed to catch any water or oil, and drains may be led from this. If after finishing the bed the timbers are found out of level, they may be easily levelled up by thin shims, or bits of wood or metal, placed between them and the engine bed-plate. In placing the motor care should be taken to see that it is so placed as to afford the greatest facility in reaching any and all parts of it and at the same time it should occupy as little space as possible. The engine may be bolted to the bed either by lag-screws through the holes in the bed-plate and well set into the timber, or by bolts put through the timbers before embedding. The bed-plate may then be set over these bolts and held in place by nuts. In either case washers should be placed between the head of lag-screw and engine bed-plate or underneath the nuts. The screws or nuts should be screwed in gradually, first at one corner, then at another; and one bolt or screw should never be fully tightened up before setting up another, as this will often bring an unequal strain and cause a crack or break in the engine bed-plate.

For large stationary motors the beds should be made of solid concrete or bricks set in concrete, and on top of this a flat heavy slab of flagstone or granite should be placed. The bed should be carried down to hard pan or at least below the frost line, and if the motor is to be placed above the ground floor of a building the bed should have solid iron columns running down to the ground. If this is not possible it should be placed as near the side or corner of the building as possible, and the portion of the floor supporting the bed should be firmly and rigidly braced. Never bolt an engine directly to floor timbers or planks. In making a heavy concrete bed the sides should slope slightly and the bolts for holding down the engine should be well set in the concrete. A good method is to insert the bolts through *iron pipe* with a nut at the lower end, and the whole

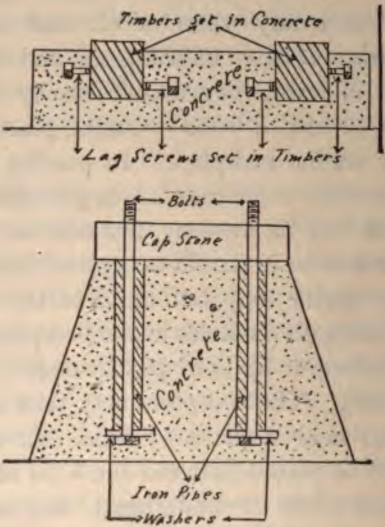


Fig. 119.—Concrete Beds

should then be embedded in the cement. Such a method is shown in section in Fig. 119.

Mufflers and exhausts on stationary engines should be well covered or protected with asbestos, for they become very hot and are liable to cause bad burns or even set fire to some object that happens to come in contact with them. Exhaust pipes, where led through a wooden wall or partition, should be protected, and a metal collar should be used over the hole with a space of at least one inch between the pipe and the nearest wood. The outer end of the exhaust should be led away from all surrounding objects or walls and should never lead into a chimney, water or steam pipe, smokestack, or other confined space. If this is done unburnt charges of gas may enter and later explode by flame or heat with serious results. If a wooden bed is used it should be firmly mortised or bolted together and should be securely fastened to the flooring or ground. Many engines are given far too light a bed, and when under full power will jump and vibrate tremendously. A good bed should be strong and steady enough to hold the motor down immovably under its highest speed and greatest load.

When installing a marine engine the method is governed to a great extent by the boat, the timbers, and the accessibility of the location. Timbers for a boat engine's bed should be of well-seasoned hardwood of ample size and strength, and should be securely bolted to ribs and keel, *but not to the planking*. A very good plan is to use two long timbers running lengthwise, or fore and aft, of the boat and fastened to the ribs. Across these the bed timbers should be bolted and these should also be securely fastened to the keel. In a flat-bottomed boat timbers may be set across the boat, bolted to keel and sides, and the engine-bed bolted lengthwise of these (Fig. 120). This method takes the jar and vibration from the floor boards and planks. Great care should be taken in getting a marine engine level and in absolute line with the shaft; a very slight deviation will cause enough friction on the shaft to stop the engine or hold it down to only a fraction of its speed and power. I have seen a ten-horse-power motor that could not be turned over more than one explosion owing to a bend in the shaft so slight as to be scarcely perceptible to the eye.

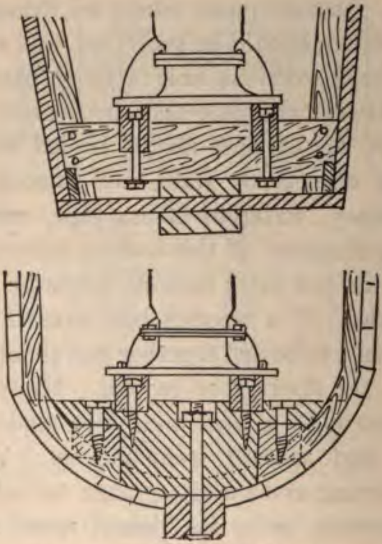


Fig. 120.—Engine Beds in Boats

Where it is difficult or impossible to get a perfect alignment, or where there is a constant vibration or motion, the shaft should be connected through a universal joint. Flexible unions, elbows, joints, and stuffing boxes may also be used if desired. In vehicle construction with a shaft drive universal joints cannot well be avoided, and in many high-powered and racing boats they are also used to great extent; but it is better to avoid flexible connections as far as possible, as they are expensive, cumbersome, and must be given considerable care if they are to prove efficient.

The exhaust piping in a boat can be so readily cooled by admitting a part of the circulating water that there is no excuse for its ever burning or scorching anything, but nevertheless it is a good plan to have it well protected and led in such a way that it will not be in the way of people passing to and fro. A marine motor, more than any other, should be handy and accessible and ample room should be left on all sides to allow it to be adjusted, taken apart, or cleaned readily, and the drain cock in base should be within easy reach. It is usually most convenient to have the exhaust on the port and the intake on the starboard side where the operator sits behind the motor, but the arrangement of such matters must be guided by the conditions in each particular case. In installing any engine the exhaust silencer should be as near the motor as possible, and the exhaust pipe should be as short and with as few bends and turns as can be arranged. Where right angles *must* be made in an exhaust pipe two forty-five-degree elbows should be used instead of one common elbow, and tees should be avoided as much as possible; they always have pockets which are a nuisance. Connections as far as possible should be made with flanges or flanged unions, as ordinary screw unions and right-and-left couplings soon become so foul and corroded as to be impossible to disconnect. The exhaust in a boat should always be so arranged as to slant downward from the motor to the outlet, for even if far above the water line a wave may now and then wash into the exhaust.

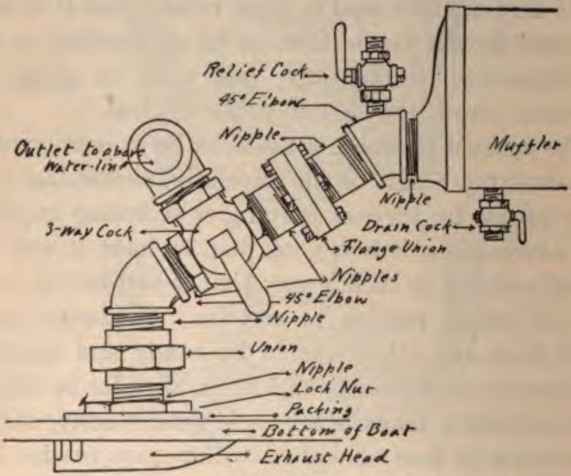


Fig. 121.—Marine Exhaust properly Installed

If a long exhaust pipe is unavoidable it should be gradually increased in size, and it is a good practice to always use a larger-sized pipe at every turn of the exhaust pipe beyond the first. For connecting up an exhaust pipe lead and oil should never be used, as it soon burns out and either leaves a leaky joint or cements the joints together into a solid mass. Cylinder oil and graphite make an excellent joint, and even linseed oil and graphite is very good. Where a solid and permanent job is desired the joints may be made with red lead and molasses, or with litharge and glycerine, or with a cement composed of sulphur, iron filings, and sal-ammoniac mixed into a thin paste with water. Well-fitting threads may also be well cemented together by the use of sal-ammoniac and water alone. Where the boat is intended

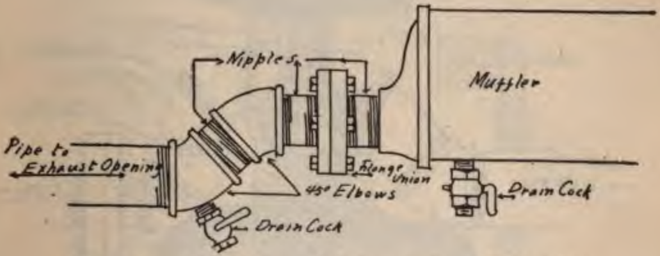


Fig. 122.—Installation of Exhaust above Water-line

for salt-water use the exhaust pipe should be of galvanized iron, and this is far better than black iron even where used around fresh water or for stationary motors. A sample of a well-installed marine exhaust is shown in Fig. 121. This illustrates an under-water exhaust, while Fig. 122 shows methods of exhaust piping when above the water line. In Fig. 123 is shown the method of properly piping a stationary exhaust where it was carried a long distance and several turns had to be made.

The water-circulation pipe connections should be made with care, for a small air leak in the intake will often cause failure of the pump, and a leak in the outlet is very messy and disagreeable in a boat and wasteful of water in stationary or vehicle use. Brass pipe is advisable in marine work, although for fresh-water use galvanized pipe answers very well. Connections on water pipe may be made with white or red lead and oil, and common unions may be used, although for many reasons flange unions are better. Turns in water pipe are not as objectionable as in the exhaust, but are to be avoided as far as possible, and the piping should always be provided with drain cocks at the lowest points in order to draw off the water in cold weather. Hose connections are bad and should never be used where they can be avoided. They are uncertain at the best and soon rot. Moreover, they become soft and are liable to collapse with suction and shut off the water supply, while pieces of the fabric or rubber are always likely to work loose and get into the pipe, valves, or pump and cause trouble. At the intake of a boat's water system there should be a

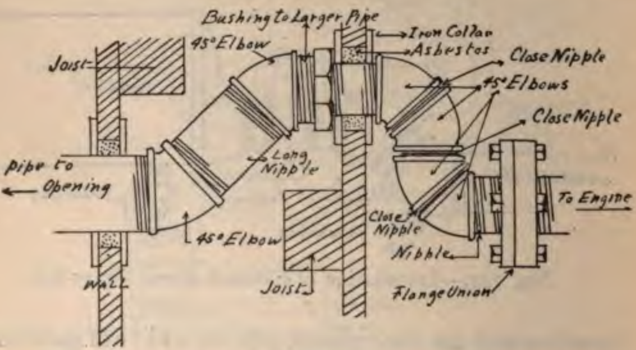


Fig. 123.—Installation of Stationary Engine Exhaust

strainer, and a cock should also be provided for shutting off the intake when not using the boat. Many a boat has filled and sunk through a loose or broken connection and lack of a valve to shut off the water. In connection with the water system, where a small part of the water is turned into the exhaust, a three-way valve will be found most useful. A valve of this sort, made by the Detroit Lubricator Co., is illustrated in Fig. 124. By the use of such a valve any amount of water desired may be admitted to the exhaust or it may be turned off completely and all the water led overboard direct.

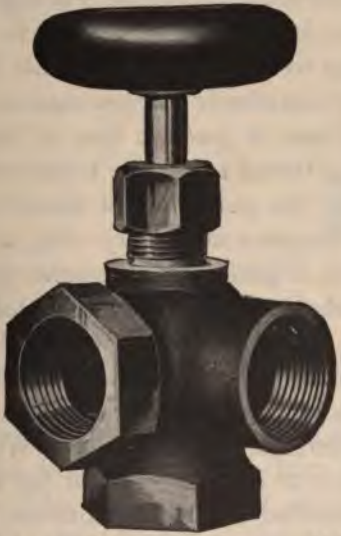


Fig. 124.—"Detroit" Three-way Valve

In making up the gasolene pipe more care should be used than in any other part of the various pipes and connections. A small leak in this pipe may result in fire and destruction or even in loss of life, for even a drop or two of gasolene now and then will produce enough gas in a boat or small building to blow it to atoms. In open boats the greatest danger lurks in the bilge or around the tank, but in cabin boats, or in cellars or buildings, the entire place may be filled with gas that will explode the moment a flame is brought into contact with it. Even in motor vehicles a leak in a pipe or tank may allow gas to form which will ignite by a short-circuited wire or a carelessly dropped cigar or cigarette, and nearly every case of gasolene fires or explosions about motors can be traced to a leaky connection or pipe.

All joints in the gasolene pipe should be made with shellac or with common laundry soap, as any material containing oils is useless. Where brass pipe is used the connections should be carefully threaded and screwed up tight. A good, clean, new thread will hold gasolene without anything else. Where a flexible tube is used it should be of soft copper and all the unions or connections should be soldered or brazed in place. Where a gasolene pipe is subject to any vibration or jar a loop or turn should be provided to absorb vibration (Fig. 125, *G*), and the pipe should frequently be looked over for breaks or cracks. A cock should always be placed at the tank so that the supply may be readily shut off (Fig. 125, *E*) and a strainer should be provided to catch any water or dirt in the gasolene (Fig. 125, *H*). Lead or block-tin pipe is to be avoided. It is easily bent or crushed, is apt to be punctured, it corrodes and forms scales and sediment in the gasolene, and in case of fire it quickly melts, thus allowing more gasolene to run out and feed the flames.

Careful attention should also be given to the gasolene tank. It should be of copper or galvanized iron of ample capacity and the feed pipe should be connected a short distance above the lowest portion. This will prevent any dirt or water in the bottom of the tank from working into the feed pipe. At the lowest point in the tank there should be a drain cock from which the collection of sediment and dirt may be drawn from time to time (Fig. 125, *D*). This drain in a boat should lead overboard and thus avoid danger of the gasolene getting into the bilge-water. A cock should also be placed in the feed pipe close to the tank so that the supply may be entirely shut off at any time (Fig. 125, *E*). The filler hole in the tank should be covered with a screw top (Fig. 125, *B*) and a small air vent made in *the side of this cap* (Fig. 125, *C*). This will allow the fuel to flow freely and also prevent dust or water from entering the

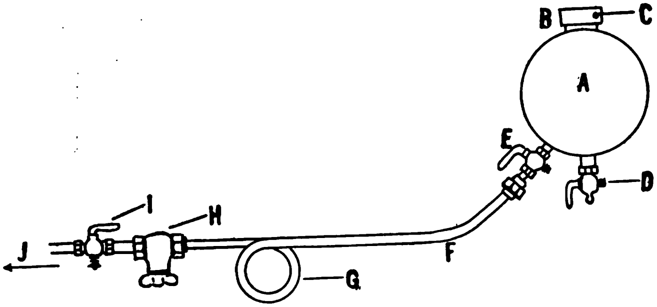


Fig. 125.—Gasolene-Pipe Installation

tank. The tank on stationary engines should have the bottom at least six inches above the highest point of carburetor, and on marine or vehicle motors it should be high enough so that any motion of the boat in a sea-way, or of the car when hill-climbing, will not bring the carburetor above the lowest point of the tank.

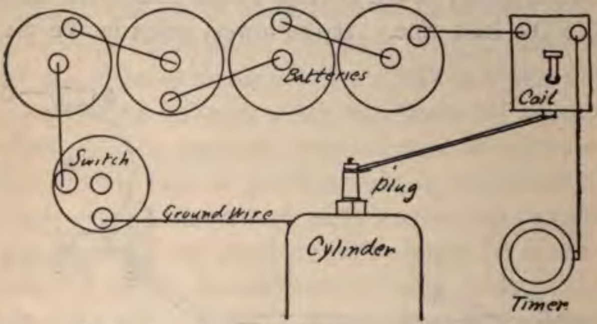


Fig. 126.—Wiring Single-cylinder Jump-spark with Batteries

Every tank should also be provided with splash plates inside to prevent the liquid from swashing about and causing irregular feed.

To many motor-owners and users the question of electrical wiring is a very serious matter. In many cases one must be a good electrician as well as mechanic to wire up a motor, but in the majority of cases the wiring is comparatively simple and easy. A description of wiring is of little use, for it is far easier to follow a diagram or design a new one suited to particular requirements by the aid of others. The makers of most motors furnish full wiring directions and diagrams with their ngines; but as motors frequently require new wiring, new systems are installed, or old motors without directions may be purchased, diagrams for wiring the various types of motors, as well as several systems of both battery and combined battery and magneto, are illustrated in Figs. 126 to 136.

In wiring for a motor, whether for marine, stationary, or vehicle use, the best materials only should be used. About 80 per cent of motor troubles are due to ignition, and a large proportion of these are due to poor or faulty wiring. Too much care cannot be taken to see that all materials are perfect, all joints well made, and that the wiring as a whole is as well done and as free from the chance of injury, breakage, or short-circuiting as possible. For primary wires in the jump-spark system, or for the wiring on a make-and-break engine, fairly

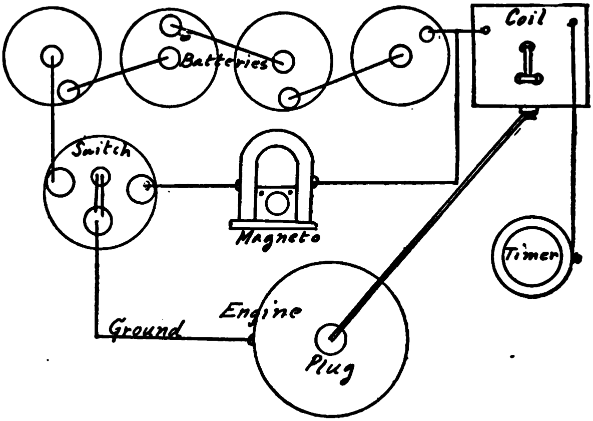


Fig. 127.—Wiring Single-cylinder Jump-spark with Batteries and Magneto

light wire may be used, but this should be of good quality, well insulated, and of the multiple-strand kind. Single-strand wire is very good, but in connection with a motor the constant vibration is liable to break, or partly break, the wire and as this is not visible through the insulation the trouble is often very difficult to locate, especially

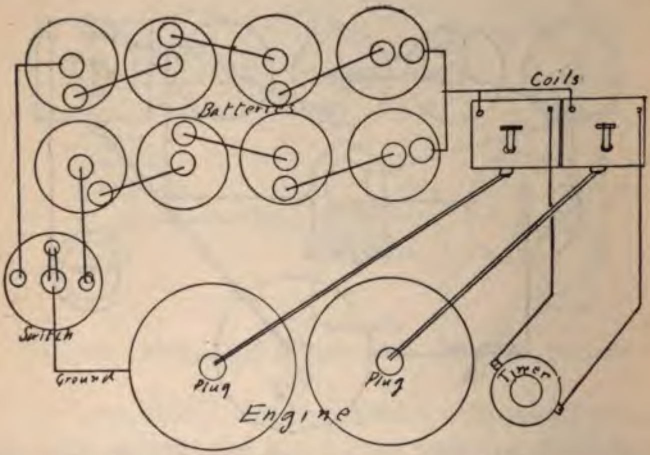


Fig. 128.—Wiring Two-cylinder Jump-spark with Batteries only

as the two ends may rub together, causing intermittent or weak connections. Where staples are used to fasten wires to seats, rails, or any woodwork, they should be fibre- or leather-covered, or when these cannot be secured, a bit of rubber, leather, or even cloth may be placed between the wire and the staple. Two wires should never be confined under the same staple, for if the insulation becomes worn or broken, short-circuiting *is almost sure* to result. Have as few joints in a wire as

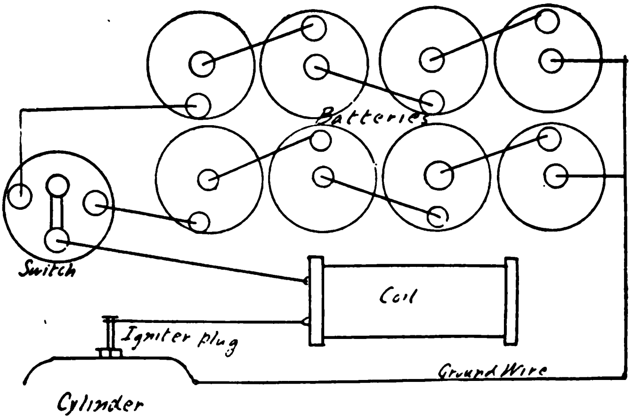


Fig. 129.—Wiring Make-and-break with Batteries

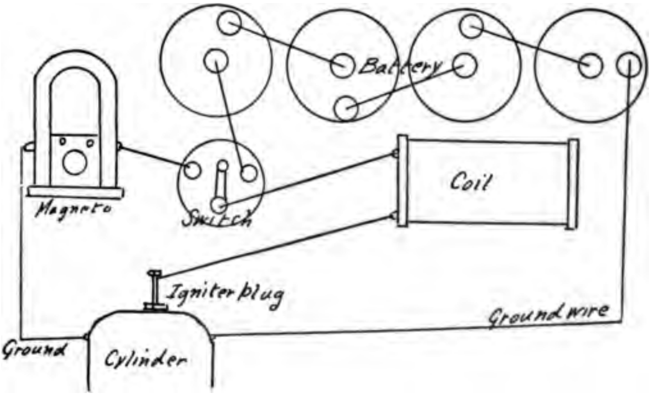


Fig. 130.—Wiring Make-and-break with Batteries and Magneto

possible, and when making a joint have the strands bright and clean and after being twisted firmly together they should be soldered. Soldering is not absolutely necessary, but it is safer, and with the modern soldering compounds, which can be used with a match or small torch or lamp, it is very easy to solder all joints. Whether the joint is soldered or not, it should be well wrapped with several layers of adhesive rubber tape.

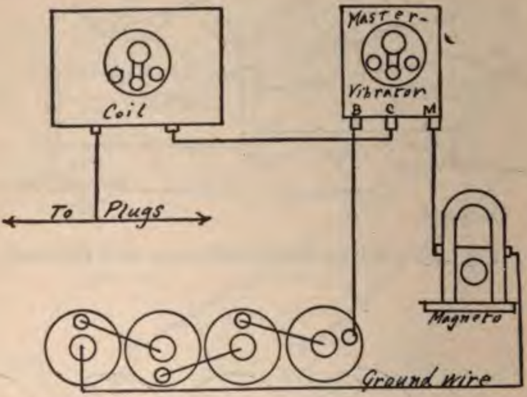


Fig. 131.—Wiring any Number of Cylinders with Master Vibrator

Secondary wire should be of the highest grade and where there is dampness or grease it should be led through a metallic or fibre tube or casing. Grease, water, and oil will in time destroy insulation and allow short-circuiting, and therefore all wires should be as thoroughly protected as possible. In marine work it is a good plan to run the secondary wires through rubber tubing and in all cases the wiring should be kept as short as possible. *Avoid confusion* of wires and keep each group separate

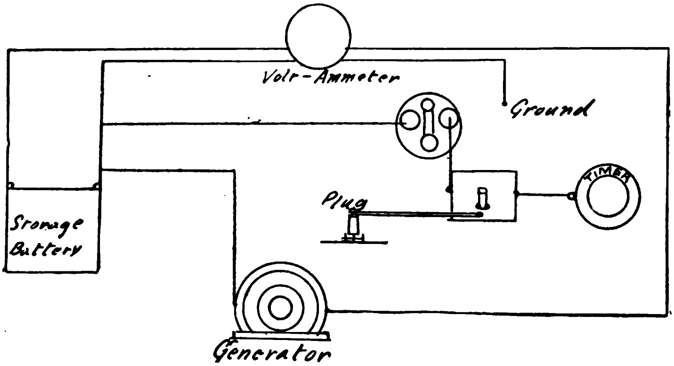


Fig. 132.—"Aplco" System of Wiring with "Floating" Storage Battery

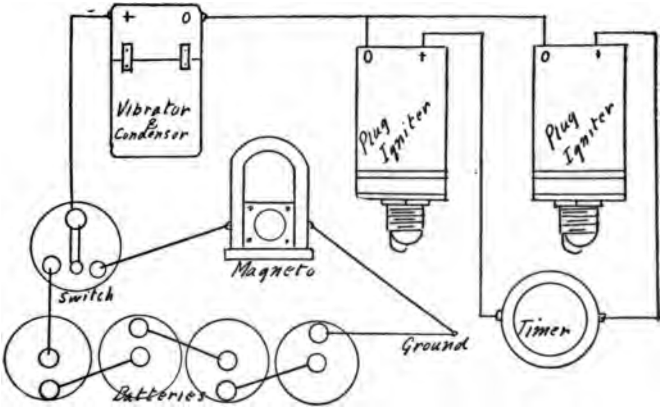


Fig. 133.—Wiring "Perfex" System

as far as possible. If wires are led under or through spaces where they cannot be readily seen and followed,

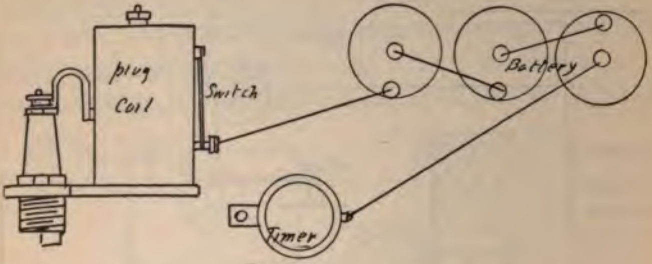


Fig. 134.—Wiring "Perfection" Plug-transformer

it is a very good plan to use various-colored wires, as in that way the wires from one place to another may be easily traced. If several different-colored wires are not

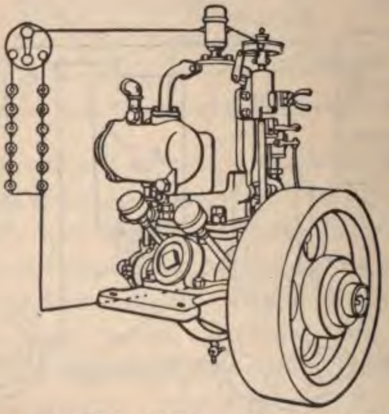


Fig. 135.—Wiring "Connecticut" Plug Coil

available, colored strings or bits of cloth may be fastened *here and there* to each wire and this will serve to identify them. Never lead a secondary and a primary wire through the same tube, staple, or insulator, but keep them as far apart as possible, and never attach either primary or secondary wires to any metal except at the terminals. If metal *must* be used, be careful to have the wires doubly or trebly insulated by winding with tape where they touch the metal.

The terminal connections of both primary and secondary wires where they connect with batteries, coil, timer, and plug are often sources of trouble and should be carefully made and frequently examined. Various styles of battery connectors and terminals are for sale and most of these are excellent. The "Bull Dog" battery connectors, as well as the various spring clip connectors, work very well; but those made from

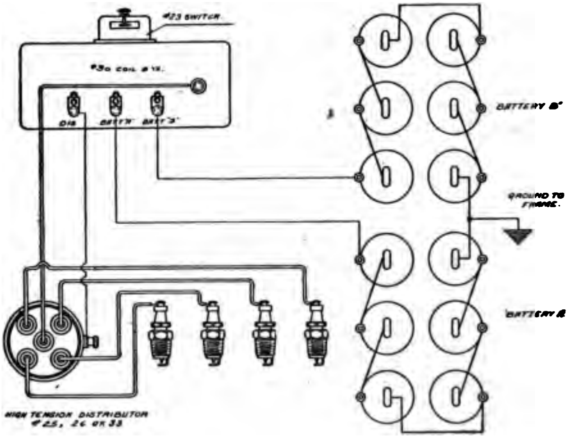


Fig. 136.—Wiring "Delco" System

a piece of sheet metal and soldered to the wires often break partly off without any external sign of the fracture and in this way cause an interrupted or weak current that is exceedingly difficult to locate. Primary and secondary terminals for the main wires come in a variety of forms and designs. A common form is shown in Fig. 137, which represents the "Reliance" terminal. These may be used by slipping over the nut or thumb screw on the top of spark plug or may be fastened by screwing the nut down over them. Another splendid style of terminal is the "Ball and Socket" form illustrated in Fig. 138. These terminals are designed to be fastened to the wire without solder or special appliances. It is only necessary to cut the wire off square, shove it into the socket, and screw the wood screw in tight. The sides of the terminal are made of spring metal with a recess to fit over the ball adapter or hexagon ball nut furnished as a part of the equipment. The use of the ball-and-socket joint allows free play of the wires in any direction and insures a perfect connection.

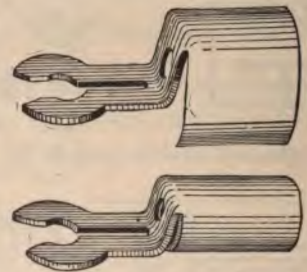


Fig. 137.—"Reliance" Terminals

Terminals which will answer every purpose may be readily made by bending the end of the wire into a loop, twisting it together and soldering it firmly in place.

In repairing, adjusting, or overhauling motors various gaskets or packings will be encountered, and as these are usually broken or injured in getting the joints apart, it is essential that the operator should know how to make new ones and be familiar with the materials to use. Gaskets are rings or sheets of material cut into the form of the parts and placed between two surfaces, such as the two sides of a cylinder head, between the two sides of a union, etc. They are made of paper, asbestos, fibre, metal, rubber, leather, etc. The best material for cylinder-head gaskets and any other places where there is considerable pressure, as well as water or gasolene, or both, is the material known as "semi-bronze",

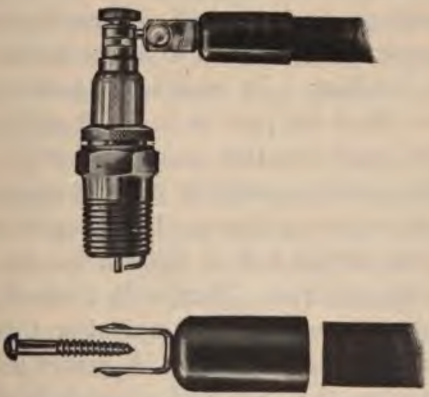


Fig. 138.—"Connecticut" Terminals

this packing consists of a fine sheet of copper-wire gauze embedded in a sheet of asbestos and covered with graphite or black lead. In many places exceedingly thin gaskets must be used, and in such spots tough manila paper well soaked in oil or grease and rubbed with graphite is the best material. Metal gaskets are used between flanges in flange unions, on exhaust connections, etc., and usually come ready-made in various sizes.

Asbestos of itself is a very poor material to use about gasolene engines, as it is frail, is readily soaked by water or gasolene, and is hard to cut or handle without tearing or breaking. In making a gasket the best method is to clean the part to be fitted and then lay a sheet of the paper or other material over it. With a smooth-faced wooden mallet or piece of rounded hardwood, tap all over the surface until the edges of the joints, as well as the various bolt or screw holes, are well imprinted on the material. Then, with a circular punch, cut the holes where indicated and after this is done cut out the edges of the joints. A gasket must never have rough edges that will bind or catch in the joints, and the holes for the bolts or screws must be smooth and ample in size. Rub the gasket with oil or oil and graphite before placing on the joint and then lay upon the surface of the joint carefully. Be sure there are no wrinkles, bits of dirt, or inequalities in the gasket and make sure that it fits perfectly before placing the other part of the joint on it. When all is ready, place the two pieces together and screw home the bolts a little at a time, working gradually, first on one side and then on another, but never tightening up all at once on any one bolt.

Packings for pump plungers, revolving shafts, stuffing boxes, etc., are usually made of cotton wicking or hemp packing. In making such a packing be sure and clean out all the old material, use packing of the proper size, oil thoroughly before putting in place, and do not pack too tight until it has formed a good bearing or seat for the shaft or other object. Never use white or red lead on a gasket or packing of a gas engine unless you are looking for trouble. Oil and graphite is the best material, and unless the packing or the ground joints are very badly made or have been abused, nothing is needed in addition.

In adjusting a new motor, or one which has been recently overhauled, you should proceed slowly, doing one thing at a time, and remembering exactly how each adjustment was beforehand and exactly how you have altered it. A valve may be ruined by turning it a trifle too tight, or a screw thread stripped or a bolt head twisted off by a slight pressure beyond the normal. In taking down or overhauling a motor each part should be marked and a similar mark placed on the part of the motor where it belonged. This may be done by light marks with a centre punch or by scratches on the paint, enamel, or metal. In taking apart a four-cycle motor this is most important in the case of the timer and valve gears. The alteration in position of a single tooth on a gear will throw the entire valve out of position. In taking apart such gears always mark the teeth, where they mesh, with a prick punch or centre punch so there may be no difficulty in placing them together correctly.

Setting the valves properly in a four-cycle motor is an important matter. The exhaust valve should open at about five-sixths of the completion of the power stroke and should close at the end of the idle or scavenging stroke. At the commencement of the next outward, or suction, stroke the inlet valve should begin to open, and both valves should be firmly closed at the moment the piston commences to travel back on the compression stroke. Different motors vary somewhat as to the exact time when valves open and close, but the above is about the average and the finer adjustments can be readily made by set-screws or other devices provided until the best results are obtained.

A gasolene motor should be cared for as carefully as any other piece of fine machinery, and because it uses oil and grease and becomes dirty in use it is no reason why it should be neglected and not cleaned and groomed frequently. A rusty, dirty, or neglected engine is a disgrace to the operator and shows lack of common sense or care. Oil cups and oilers, as well as grease cups should be kept well filled and all excess oil or grease carefully wiped off. If grease and oil accumulates or sticks on, it should be removed by kerosene and gasolene. All unpainted parts should be kept clean and free from rust and well oiled, and all nickel or brass work should be kept brightly polished. If you cannot spare the time to polish and clean your brass it is better to paint it at once and avoid horrid green verdigris. A vehicle motor requires as much care as any other, and because it is out of sight it is all too frequently out of mind as well. Many a splendid motor-car, that is resplendent in polished brass, rich upholstery, and shining paint and varnish, carries beneath its hood a motor so greasy, dusty, dirty, and neglected that it would be a disgrace to the most slovenly fisherman's dinghy.

CHAPTER VIII

TOOLS; EMERGENCY REPAIRS AND MAKESHIFTS; USEFUL HINTS AND WRINKLES; GRINDING VALVES AND GRINDING COMPOUNDS; CARBON-REMOVERS AND CLEANSERS; POLISHES; ENAMELS, PAINTS, ETC.; BELTS AND BELT DRESSINGS; ANTI-FREEZING MIXTURES; TABLE OF MOTOR TROUBLES WITH CAUSES AND REMEDIES.

FEW motor-owners realize the importance of being provided with proper tools, and this is especially true where marine or stationary motors are concerned. Every motor should have a tool box or chest or a tool-roll within easy reach, and the tools should always be kept in good condition and ready for use. Many a motor-operator may be found whose only tools are an old rusty bicycle wrench, a dull or bent screw-driver, and an old claw hammer. Tools are cheap and comparatively few are required. A superabundance of tools is a nuisance, and the aim of the operator should be to have a tool for every emergency and for each particular use, but not to duplicate them. The following tools are really essential in connection with any motor:

A "Stilson" or pipe wrench capable of handling any pipe on the motor; if this cannot be procured, owing to the variation in size of pipes, two or more Stilson wrenches should be on hand.

A monkey or "Coe" wrench large enough to handle the heaviest nuts and unions on the engine or exhaust.

A small "Coe" wrench capable of handling the smallest nuts; a good bicycle wrench will answer for this, or a set of spanner wrenches to fit the various nuts may be used.

A medium-sized — six- or eight-inch — "Westcott" wrench or a set of "S" wrenches.

A pair of combined cutting pliers and tweezers.

A pair of round-nosed pliers.

Small, medium, and large-sized screw-drivers, or a set of screw-driver blades with an adjustable handle.

A small or medium-sized machinist's hammer with round pein.

A half-inch cold chisel.

A centre, or prick, punch.

A hollow punch.

A flat or "bastard" file, a round file, and a three-cornered file.

An assortment of copper and iron wire of various sizes.

Assorted machine screws. Assorted cap screws and nuts. Assorted plain and lock washers. Assorted cotter pins.

In case there are any nuts or bolts which cannot be readily reached with an ordinary wrench, socket wrenches should be provided, for such nuts or bolts are invariably the ones that need attention oftenest.

In addition to the above tools there are many others which will prove very useful at times, especially if you expect to make your own repairs. A breast drill with a good assortment of drills is a useful and handy tool, and a bit-stock with various-sized twist drills is also very useful. By drilling a small hole with the breast drill, a large twist drill will readily bore through iron or brass with an ordinary bit-stock, the larger drill following the small hole very easily.

In connection with the drills, reamers and countersinks should be on hand, and if much metal-boring is to be done a self-feeding chain attachment for the bit-brace should be added. By means of this handy tool large holes can be rapidly and easily bored through iron or steel without any great trouble or strength being required. Hack saws are very useful and in fact almost indispensable, and screw slotters to fit the hack-saw frame will save much time and trouble in using old screws. An exceedingly useful tool is the Vixen milling tool. This is a hardened steel blade with sharp, curved teeth and is used like a file. It will cut ten times as rapidly and easily as a file and will never clog, even when used on lead, copper, or aluminum. New blades may be purchased at a small cost and the old ones recut or sharpened at trifling expense, but under the severest use a blade will usually last two years or more.

Machine taps and dies are very useful and save many times their cost in a season, as well as the trouble of running to a machine shop for every screw thread you want cut. Pipe taps and dies are also handy, but most pipe fittings are so cheap and so readily procured that they hardly pay unless one does considerable pipe-fitting or is a long distance from a dealer in pipes and fittings. Calipers are useful, and an assortment of cold chisels, cape chisels, and punches will prove of great value.

Every motor-owner should learn the proper use and care of tools, for a rusty, dull, or broken tool is worse *than none* at all, and there is no excuse for keeping tools in poor condition. Around salt water tools rust very quickly, but if greased every few days the corrosion will not cause any trouble. You should not expect to work metal as easily as wood, even with the best tools, and many a good tool is injured or broken by trying to force it. Slow and sure is the way to work metal, and trying to drill too rapidly is sure to result in broken drills, while using too much force on a nut or bolt will result in stripped threads or broken bolt heads. A very light blow with a hammer will often start a nut or joint, but wherever the surface struck joins another surface a piece of hardwood or a strip of copper or lead should be placed over it before striking. Great care should be used in striking cast iron, or a crack or break will result; high-grade cast iron will chip or crack almost like glass and a hammer should never be used without wood or soft metal under it when striking cast iron. Sometimes an obstinate nut or bolt may be readily started with a cold chisel and hammer, but you should not use enough force to shear off a corner of the nut. Hold the chisel at an angle against one side of the nut and strike gently. After it is started the burr made by the chisel should be smoothed off with a file. Turpentine is very useful in drilling, sawing, or filing metal, and many tight pipe joints or screw threads will come apart easily after soaking a few hours in turpentine. Kerosene is good also, and in case a pipe joint or thread is badly stuck it may be soaked in kerosene and then ignited. The burning kerosene will usually expand the joint enough to break the corrosion and then by soaking in turpentine the joint will be easy to separate.

Sometimes, even with the greatest care, a cap-screw or stud will break off in the hole. To remove the broken piece is often very difficult and sometimes it is absolutely necessary to rebore and thread the hole. Many times, however, the stub may be unscrewed by boring a hole in it and tapping with a left-handed thread of smaller size. By screwing a left-handed screw into this and setting up tight the tendency will be to unscrew the right-hand thread on the broken stub. Many times a bolt or screw thread becomes badly worn or rusted and the bolt or nut will not hold. Usually it is always best to retap the hole and use a new bolt, but in many cases such methods are impossible. At such times the thread may be made to hold like new by slitting the end of the bolt or screw and spreading the sides slightly, or in the case of large bolts by driving in a small wedge (Fig. 139). If the nut is worn and the bolt is all right, the former may be made tight by heating to red heat and then sprinkling cold water around the outer side. This will shrink the nut considerably and result in a snug fit. The application of heat for expanding metal is often very useful, and many joints can be taken apart or put together when hot that cannot be started when cold.

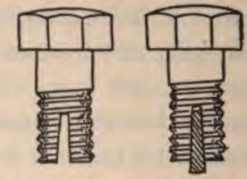


Fig. 139.—Tightening Old Bolt

Loose sprockets, cams, wheels, etc., can all be made very tight by expanding the pieces with heat and while still hot putting them together and allowing them to shrink to a close fit. Sometimes a nut which is not held by a lock washer or cotter pin may become loose and give considerable trouble. This may be easily overcome by sawing a little less than half-way through the nut and then springing the two parts close together. A nut treated in this way will hold like a lock nut and will never loosen (Fig. 140). Care should be taken, however, not to cut the slit too deep or too wide, or the threads will be stripped in screwing it on.

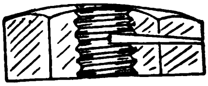


Fig. 140.—Slit Locknut

Very often one requires a pipe-fitting of a smaller or larger size and has no reducer or bushing at hand. At such times the man provided with pipe taps and dies may make excellent reducers by using short pieces of standard brass pipe. In brass pipe each size will thread inside for the next smaller size: thus ¼-inch pipe may be threaded for 1/8; 3/8 for 1/4; 1/2 for 3/8; 3/4 for 1/2; 1-inch for 3/4, etc. Iron pipe will not thread so accurately, but in many cases a thread can be cut in iron pipe that will answer for an emergency. Pipe-couplings may also be used as reducers by threading the outside for the next larger sized fitting, but they are harder to handle and do not make as good reducers as the pieces of brass pipe.

In threading brass rods it will often be found that the same sized die as the nut used will not allow the nut to be screwed on. In such cases the rod should be slightly filed down or rubbed with emery before threading. Brass has a tendency to bind when it fits tightly, and threads on brass can always be made with more play than on iron. In using 1/4-inch machine thread nuts it is often advisable to use a No. 14 thread with the same pitch in threading bars for the nut.

If you should require a pipe wrench and have none at hand you can often handle a pipe successfully by placing a three-cornered file in a monkey wrench and using this on the pipe (see Fig. 141). Old files that are clogged and dull may be readily cleaned and made as good as new by soaking for a short time in sulphuric acid and water. *The sol*ution should be weak—about 1 ounce of acid to *2 quarts of* water—and after soaking a few hours the

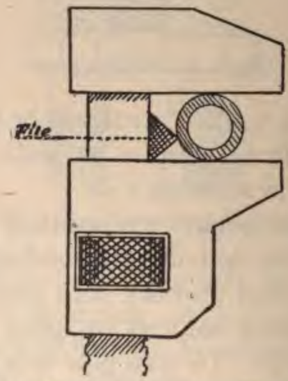


Fig. 141.—Monkey-wrench as Pipe Wrench

files should be washed thoroughly in a strong soda solution, brushed off clean, and dried by heat and then oiled.

In plugging old holes with bolts or pipe plugs there is often great difficulty in getting them to hold tightly and not leak. This is often the case in holes tapped in water jackets where the metal around the hole has rusted away until so thin that it will not hold the thread. Such holes may be covered by brazing on a piece of metal or by fastening a patch of metal over the hole by means of several small screws and a packing between the jacket and the patch. The former requires a professional brazer, while the latter takes considerable time, and if the jacket is rusted badly you may find several holes to plug instead of one covered up. A very good method under such conditions is to file the hole oblong or oval, as shown in Fig. 142, *A*. Then cut a piece of stiff brass or soft steel or iron just large enough to slip into the hole (Fig. 142, *B*). Bore a hole through the centre of this piece and fasten it on the end of a short bolt or screw by threading and rivetting (Fig. 142, *C*). Thread the bolt or screw on the other end almost to the piece of metal. Slip the metal piece into the hole and turn around so that the long ends are across the short diameter of the hole. Put a piece of packing over the projecting bolt (Fig. 142, *D*), place an iron or brass patch over the packing (Fig. 142, *E*), and screw the whole down firmly against the outside of the jacket by a nut on the threaded bolt as illustrated in Fig. 142, and it will be found a most satisfactory way to stop up old holes or leaks in many places. If the cylinder is a small and had been discarded, the chewing-gum patch was still tight and firm. If small leaks occur in the pipes or radiator they may be temporarily stopped by sprinkling fine cornmeal or bran in the water. This should be done *while the engine is running* or trouble will result. The meal or bran finds its way to every crack and cranny in the system, and where there is a leak it clogs the latter and swells tight. If the meal is placed in the water when the motor is idle it will form masses in the joints and curves and cause complete stoppage of the circulation. One of the worst cases of overheating I ever saw was caused in this way. The meal or bran should be scattered in the water slowly and gradually, and very little used; generally a couple of large spoonfuls is enough.

Sometimes a bearing will become worn or cut and lose compression when it is impossible to get new ones without laying up the motor for some time. Bearings that are loose may often be tightened up by means of a set-screw placed in the bearing box as shown in Fig. 143. With bearings made in cylindrical form this of course cannot be done, but with split bearings it often works very well.

Occasionally you may have some soldered joint come apart or work loose when no soldering appliances are available. It will be very difficult to resolder such a joint unless a gasolene torch is at hand, but if you are in an automobile and have gas or acetylene headlights the joint may be readily sweated or brazed together in the intensely hot flame of these lamps. It is always advisable, however, to be provided with some one of the various prepared soldering compounds which may be used with a common match or oil lamp, or even with a candle.

One of the commonest troubles with four-cycle engines is leakage around the exhaust valve. As soon as the valve becomes pitted or worn it must be reground, for otherwise the hot gases will rapidly cut and burn away the valve until the motor is powerless. It is very easy to grind in a valve, and yet many owners and operators never attempt to do it but go to a repair shop or garage and pay to have it done, and very often poorly or improperly done at that. To grind in a valve the spring and foot must be first removed. This is often very easily done by hand, but in some cases it will be found difficult to get out the cotter holding the foot in place without holding the spring up by mechanical means. Various valve-lifting devices may be purchased for doing this, but a home-made affair as shown in Fig. 144 will answer every purpose. After the spring and foot are removed lift out the valve from its seat and clean the surface of valve and seat thoroughly. If the valve chamber is

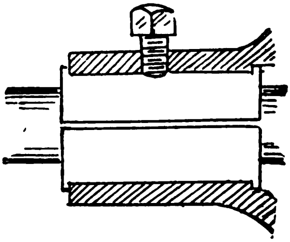


Fig. 143.—Set-screw to Tighten Bearing

readily removed from the cylinder it is best to do so; but if not, the cylinder should be thoroughly plugged with rags or cotton waste. Now spread a thin layer of fine emery and cylinder oil on the surface of the valve and place in its seat. With a screw-driver inserted in the slot on top of the valve, press the valve firmly down and while exerting a steady pressure turn it rapidly back and forth on its seat. Lift the valve occasionally and turn it to a new position and continue rotating. After a few minutes you will find the grinding or "gritty" feel of the valve has disappeared and that it moves about more smoothly and quietly. Now remove the valve and wipe off all the emery and oil on the valve face and seat. If a clean bright surface shows all around, the valve *is sufficiently* ground, but if spots or streaks of dull or

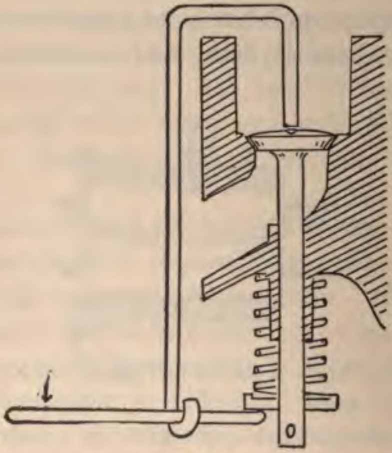


Fig. 144.—Valve-lifter

black metal show here and there the operation should be repeated until the entire surface is smooth and bright.

In grinding be careful not to press down too hard or to get dirt or filings mixed with the grinding mixture, or the valve will be ruined. After the grinding is complete the seat, valve, surfaces around the valve seat, and all other parts where emery may have lodged should be carefully wiped and cleaned, for a minute quantity of emery getting into the cylinder will soon ruin it or a little left under the valve will soon cut it worse than before. Some valves are not provided with a slot in the top for a screw-driver, and in such cases there are generally two small, round holes. With valves of this sort you should use either a regular tool made for the purpose or should make a tool from an old auger as shown in Fig. 145. After the valve is ground and in place you should examine the stem to see that it does not project so far that it always touches the tappet or push-rod when the latter is in the position for the valve being closed. If the grinding has allowed the valve to drop down until this occurs,

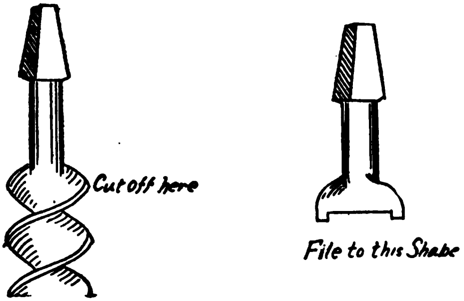


Fig. 145.—Valve-grinding Tool

the tappet or rod should be filed off until about 1/32 of an inch is left between the end of the valve stem and the push-rod or tappet. Never file off the end of the valve stem, as in this case a new valve will prove too long when placed in the old seat. New valves should always be ground into the seats, and a newly ground valve will never be quite tight until it has been operated for some time.

Emery and oil is an excellent grinding compound, but Tripoli, rotten-stone, or very fine pumice will give a smoother and more beautiful finish, although the grinding will take longer with these materials than with emery. Various valve-grinding compounds are on the market; and some of these that are composed of carborundum, and come in the form of a paste in collapsible tubes, are the finest and handiest of preparations for grinding valves. Being in a tight tube and already mixed, there is no danger of foreign matter or grit getting in and the consistency of the compound always remains the same. A tube of this material should be in the kit of every user of a four-cycle motor.

Even when the valves are well ground in and perfectly adjusted a motor will sometimes lose compression and yet it will be next to impossible to discover the joint or crack where the trouble occurs. At such times the leak may be readily located by squirting soapsuds around each joint while the motor is running. Wherever a leak occurs the suds will form bubbles and you will often be surprised to find how many unsuspected leaks there are in your motor when you test it by this method.

A great deal of valve trouble may be avoided by placing a small ball race or thrust between the spring and valve foot as shown in Fig. 146. When this is done the valve revolves slightly each time it seats, and is thus continually resting on a new spot, causing less wear and liability to cut or pit.

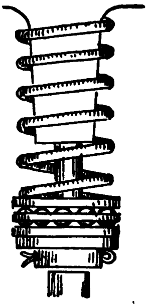


Fig. 146.—Valve with Ball-race

A great many compression leaks may be traced to the priming or relief cocks. These cocks become exceedingly hot through their direct connection with the interior of the firing chamber and are therefore subject to very severe conditions. In order to be gas-tight they are provided with a stiff spring to hold the conical valve in position, and the heat frequently destroys the temper of this spring and allows the valve to shake loose. Oil and gasolene also tend to gum up the cock and prevent it shutting gas-tight, and often the cock will leak considerably without visible evidence. A cock manufactured by the Morgan Mfg. Co. of Newport, R. I., and designed to overcome the many difficulties of spring seating cocks, is illustrated in Fig. 147. This is a distinct advance in this line of accessories and is a good illustration of how little things can be improved to add greatly to the efficiency and service of a motor.

Many motor troubles are caused by an accumulation of soot and carbon in the cylinders, firing chamber, valve chambers, or one of the spark plugs or sparking electrodes. The quickest method of removing such deposits is by using one of the various carbon-removers on the market. Care should be taken in using these to see that none of the compound is left in the motor or the crank case, as they will injure the engine unless thoroughly removed and the parts well oiled afterward. Only light deposits and gummed oil can be thoroughly removed in this way, and for such accumulations plain kerosene oil will work almost as well and is safer and cheaper. Where the deposits have become thick and hard they must be removed by scraping and to do this the cylinder head and other parts must be removed. To thoroughly clean the carbon deposits from a neglected motor is a disagreeable, dirty, and tiresome job; but with decent care and attention there is no need of ever being obliged to do it. Good oil, and not too much of it, will prevent carbon from forming; and if once in a while the cylinders are wiped out with kerosene, and the spark plugs and valves cleaned, there will be no danger of *being* troubled with carbon and soot.

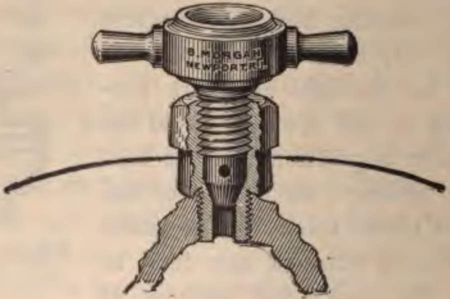


Fig. 147.—"Morgan" Priming-cup

In removing piston rings great care should be used, as these are very brittle and break easily. By spreading the rings slightly with a pair of pliers, as shown in Fig. 148, and then inserting strips of thin tin or brass beneath them, they will slip off easily (Fig. 149); new rings should be put on in the same way. The last or lowest ring should be taken off first and the others in regular order, and in replacing them the reverse order should be followed, as otherwise the rings will slip into the empty grooves and cause lots of trouble.

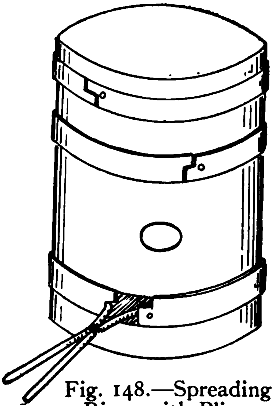


Fig. 148.—Spreading Rings with Pliers

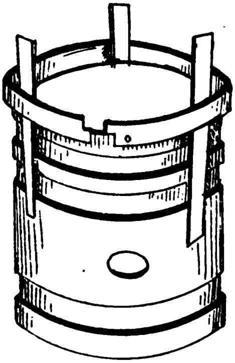


Fig. 149.—Shims for Removing Rings

Special pliers should be used for spreading the rings, as they must work in exactly the opposite manner from ordinary pliers; that is, the nose should open instead of shut when the handles are brought together. Such pliers may be purchased ready-made, but are easily constructed from pieces of steel rod bound together with wire for a joint as shown in Fig. 150. Oftentimes rings will fail to hold compression when they are not worn out, through oil becoming gummed and hardened in the groove, thus preventing the rings from moving about or springing properly. If the grooves are found filled with hard oil they should be thoroughly cleaned and freshly oiled before replacing either old or new rings. If the rings show smooth and bright all around it proves that there is no leakage past them, but if blue-black or discolored spots show it indicates a leak. In cylinders with separate heads, where the piston is lifted up through the top, it is often very difficult to replace the piston and rings. By placing bolts or screws in the stud holes of the cylinder and pushing wooden wedges between these and the rings, the piston may be easily replaced (Fig. 151, *W*). Strips of brass or tin may also be used as shown in Fig. 152, *S*, *S*, and will save trouble and broken rings.

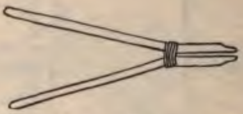


Fig. 150.—Pliers for Spreading Rings

Most engines have considerable bright brass work about them, and it adds greatly to the appearance of any motor to have this kept bright and clean. Hundreds of metal-polishes are on the market and some of these are good, some poor, and some will destroy the metal faster than they polish it. Avoid any polish that cleanses by chemicals or acids. Any polish that smells of ammonia or that will affect litmus paper for an acid test should e avoided by all means. Such polishes will give a quick and brilliant finish, but the surface of the metal will corrode all the faster afterward and will soon become eaten and pitted until ruined. It is far safer and better to make your own polish and it will cost far less in the end. For rough work, where old corroded brass is to be cleaned, cylinder oil and the finest pumice stone may be used, but for ordinary work or on brass that is in good condition a mixture of rotten-stone and oil, crocus powder and oil, jeweler's rouge and oil, or oil and whiting should be used. If a more liquid polish is desired, a little kerosene may be added until the desired consistency is obtained, while a paste may be made by adding hot paraffine or tallow until the mass partly solidifies when cold. After polishing with any of the above a highly finished result will be obtained by wiping with kerosene and rubbing with precipitated chalk.

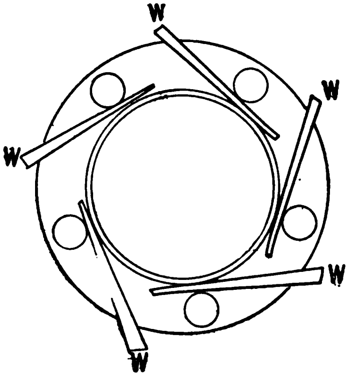


Fig. 151.—Wedges for Putting in Piston

Steel or iron that has become rusty but should have a bright finish may be polished by scouring with emery and oil or emery paper, and afterwards finishing with pumice and oil or rotten-stone and oil. It is better, however, to finish all iron and steel with paint or enamel. Any good engine enamel will answer for most places, but on the exhaust and cylinders a special enamel should be used. For cylinders the highest-grade engine enamel should be used or an enamel made by mixing the color desired with the best quality Japan varnish.

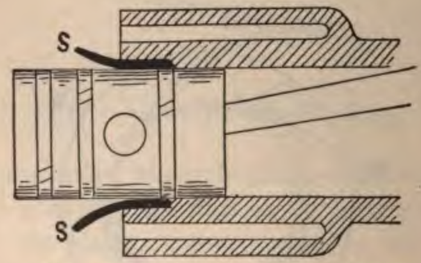


Fig 152.—Shims for Inserting Piston

On exhaust pipes and mufflers few paints or enamels will stand, but graphite mixed with linseed-oil will last longer than any other compound. Before applying paint or enamel to any part of a motor the portion to be painted must be thoroughly cleaned from grease or oil and smoothed bright and clean with emery paper. Old paint or enamel should be smoothed off with emery paper, and if any looseness or cracks appear the old paint should be burned and chipped off to the iron. Parts that rub or bear together, or bearings, should not be painted; many troubles have been caused by painting springs, valve stems, carburetors, igniters, and wires.

Where belts are used there will often be trouble with their slipping, especially where the drive is short. Around water, or in boats, leather belts should be avoided. For pump drives, etc., wire-coil belting or sprockets and chains are better than anything else, but even wire belts will at times slip on the pulley wheels. When this occurs wrap two or three turns of adhesive tape around the wheel in the groove, being careful to have the tape wound in the direction of drive so it will not work up. Cotton-web belts are better than leather in most cases, and rubber is also excellent; while for very long drives nothing excels good manila rope spliced together. When belts slip they should be treated with some compound or belt-dressing. Many excellent dressings are on the market, but I have found that resin dissolved in gasolene and sprinkled on the belt is the best thing in an emergency. This should not be used freely on leather belts, however, for the gasolene soon ruins the leather. Perhaps the best material for making a belt stick and pull is common tar soap. By holding a cake of this against a moving belt it can be evenly distributed and the belt will at once cease slipping.

In winter time some provision should be made for preventing water from freezing in the tanks, pipes, radiator, and jacket of stationary and vehicle motors. In marine engines the water may be drained off to prevent this trouble, but in automobiles and stationary engines it is better to add some substance to the water. Glycerine, calcium chloride, salt, and various other substances are used, but these are all more or less injurious to metals or rubber pipe. The best material is denatured alcohol. This is cheap, it will not injure any portion of the motor, and it will prevent freezing even at the lowest temperatures. It is better to keep too much rather than too little alcohol in the water, and as the alcohol evaporates rapidly when heated it should be kept up to its proper percentage by adding more alcohol from time to time. When all danger of freezing is past, the water should be thoroughly drained off and new water put in its place. I have usually found that a 10-per-cent solution of alcohol (1 gallon to 10 gallons of water) is safe, and it is very seldom that the temperature goes low enough to endanger a mixture of this proportion. If alcohol cannot be procured, a solution of equal parts of glycerine and water, or a solution of 5 pounds of calcium chloride to a gallon of water will prove perfectly safe. A solution that is said to be non-corrosive and will withstand a temperature of 20 degrees below zero is made by combining 75 parts of carbonate of potash with 50 parts of glycerine and 100 parts (by weight) of water.

TABLE OF TROUBLES, CAUSES, AND REMEDIES.

Trouble	**Cause**	**Remedy**
Air lock, circulation poor, and motor heats.	Air in water-pipes; pump broken or stuck; leak in intake water-pipe; slip of belt drive to pump. Dirt in check valves.	Mend leaks, or if air-lock, prime pump or pour water through pipes. Open and clean check valves and force water back through intake pipe.
Back or premature explosion; pre-ignition; knocking when running. When starting, motor reverses.	Timer advanced too far. Motor overheated. Too much oil, causing carbon deposit in cylinder. Spark plug rusty or dirty, thus allowing the points to become red hot. Short circuit in timer.	Retard spark. Look after water circulation. Clean cylinder from carbon and feed less oil. Remove and clean spark plug or replace with new one. Clean insulation and wires at timer, or replace.
Batteries exhausted. Sluggish action of motor. Misfires. Engine stops and after standing a short time starts easily but again misses and stops.	Batteries old or wet. Two batteries in contact, thus short-circuiting. Wires or connections loose or broken. Spark-plug points broken, dirty, too far apart, or too close together. Vibrator worn or pitted or irregular in action. Make-and-break igniter out of adjustment or interior electrodes worn or dirty. Rocker	Test batteries. Replace with new ones. Place strips of wood or card between cells. Replace wires and tighten up all terminal connections. Look for broken, worn, or water- or grease-soaked insulation. If fastened with staples remove them. Put in new plug or clean and adjust old one. Test, clean, and adjust the vibrator.

Trouble	Cause	Remedy
	spindle stuck or broken. Springs too weak or broken.	If make-and-break igniter, work spindles by hand and clean with kerosene. Clean interior electrode and mica packing. Place new springs on igniter.
Bearings squeak, pound, jar, shake, rattle, or heat.	Bearings too loose, too tight, dirty, wet, worn, or lacking oil.	Loosen up or tighten bearings as required. Clean with kerosene and lubricate thoroughly. If babbitt is cut, worn, or melted out, it must be replaced.
Blow-back. Popping noises in carburetor or intake pipe. Explosion in the carburetor or flames.	Worn or pitted inlet valve or check valve in carburetor weak. Dirt in inlet valve or check valve stuck. Poor mixture or timing.	Regrind valve. Renew springs. Clean valves. Clean inlet-valve stem with kerosene. Readjust carburetor and timer.
Carburetor. Sluggish operation, irregular running, runs well at slow speed and badly at high, or *vice versa*. Carburetor floods or backfires.	Gasolene supply low, pipes choked with dirt or air, water in gasolene, filter choked; needle valve bent, worn, or dirty; float broken, loose, or water-soaked. Float valve stuck, dirty, or bent. Air-intake choked, loose, or spring broken. Poor or stale gasolene. Carburetor adjustment poor. Check-valve spring too weak or	Try flow of fuel through pipe from tank. Blow back through pipe until gasolene runs freely. Drain gasolene from bottom of tank and from carburetor into glass and examine for dirt or water. Examine float and float valve. Remove needle valve and flush with clean gasolene. Readjust carburetor. Try new check-valve springs.

Trouble	**Cause**	**Remedy**
	too stiff, broken, or stuck. By-pass or inlet valve choked or dirty.	
Coil buzzes weakly or irregularly. Operation uneven. Sparks brightly at vibrator points. Buzz inside coil. Buzzes when timer is not in contact or when switch is off.	Pitting or wear of vibrator contacts. Wrong adjustment. Batteries weak or short-circuited. Vibrator spring too weak or too stiff. Coil burnt out or wet. Insulation worn out or broken. Short-circuit in coil or timer. Timer worn.	Clean contacts and smooth with fine file. Try various adjustments of vibrator. Test coil and batteries for amperage. Try new spring on vibrator or try motor with new coil. Overhaul all wires and connections. Clean and examine timer.
Compression poor or leaky. Engine loses power and shows little resistance on the compression stroke when turned by hand. Sound of escaping gas when turned slowly. Hard to start. Misfires. Overheating of base.	Valves pitted, worn, dirty, or stems stuck. Valve springs too weak. Cracks in cylinder or combustion-chamber walls. Poor packing at cylinder head or base joints. Rings worn, broken, with lap-joints in line, or stuck in grooves. Broken or cracked spark plug. Compression or priming cup worn, broken, or dirty. In make-and-break motors bearings worn or leak around igniter.	Examine, clean, and, if required, grind valves. Clean and try valve stems. Put on new springs. Squirt oil or soapsuds around various joints and look for bubbles. Place new gaskets in joints. Examine rings and if burnt spots show, replace with new rings. See that rings are pinned in place. Clean grooves for rings in piston. Test priming cup. Try new bearings and test bearings, igniter, and any other joint with soapsuds.

Trouble	Cause	Remedy
Compression entirely fails. Motor will not start. Wheel turns freely clear through compression stroke.	Governor stuck or broken. Valves either broken or stuck. Cam, push-rod, or gears broken or slipped. Valve springs stuck or broken. Cracked or broken cylinder. Broken crank or connecting rod. Badly broken ring or scored cylinder.	Try same as last, and if not located, take engine down and thoroughly examine all parts.
Compression. Too much resistance to turning over wheel, making motor hard to start. Will run free or idle, but will not carry load. Will run a few turns in one direction and then reverse and run a few turns backward and stop.	Not really due to compression. Piston badly worn in one spot, causing it to bear on cylinder. Piston pin or connecting-rod bearings worn so piston cants and jams in cylinder. Bent crankshaft, connecting rod, piston pin, or propeller shaft. Too tight bearings or stuffing box. Bed, bearings, or shaft out of line. Couplings on shaft out of true. Piston hits shoulder at top of cylinder or spark plug. Carbon on top of piston or in cylinder near end of stroke. Piston not enough lubricated. Too much friction somewhere.	Detach motor from drive shaft. If operation is now all right, trouble is in shaft beyond motor. Clean cylinder and piston. Adjust bearings, loosen motor from bed, and try with some free motion on bed plate. Run kerosene through piston and lubricate thoroughly. If piston or cylinder is worn, replace or try new rings. Loosen up on each bearing in turn until trouble is located.

Trouble	Cause	Remedy
Connecting rod or crank shaft pounds or knocks. Loud clanging noises and sudden stoppage.	Pre-ignition. Cylinders badly timed so that two cylinders fire against each other or one too early and another too late. Reversing too suddenly. Spark too far advanced. Mixture wrong. Broken ring, piston, bearing, connecting rod, shaft, crank, or melted or burned-out crank bearings. Piston seizing through lack of oil. Water leak in cylinder through crack or leaky priming cup, or around igniter. Water in base. Faulty packing allowing water to get into cylinder. Packing in joints too thin, allowing piston to strike edges of flanges at base.	Remove cylinder or head and look for carbon deposits. Try retarded spark. Examine valves and test for proper timing of same. Examine bearings, connecting rod, and shaft. Try new rings. Adjust carburetor. Examine inside of cylinder for water. Drain base and lubricate well. Put in thicker packing.
Cylinder pound or knock. Loss of power. Misfires. Loss of circulating water. Steam from exhaust.	Crack in cylinder or water jacket. Leak around packing in head or jacket. Porous iron in casting. Blow-holes in casting. Leak around pipes or cocks in cylinder. Scoring of cylinder.	Proceed as in last and try each part until trouble is located. First try thorough lubricating and cleaning. If a sonoscope is at hand try to locate pound with this. A loose fly-wheel will cause an engine to

Trouble	Cause	Remedy
	Broken rings. Loose piston pin or connecting-rod bearings. Badly worn cylinder. Loose piece of metal in cylinder. Loose flywheel. Loose gears. Broken igniter. Loose bearings. Carbon deposit. Poor water circulation. Pump gland striking eccentric rod or plunger. Poor lubrication. Loose or worn eccentric straps.	pound badly and will be hard to locate. Tighten up nut on same and use a new key.
Flare-up. Flame at the carburetor or around intake manifold. Back explosions.	Leak in pipe line or connections and short circuit, causing spark that ignites same. Poor or weak mixture. Gasolene in base. Valve or check stuck or in bad shape, thus allowing burning gas to blow back and ignite gasolene in carburetor. Leak around the manifold or intake-pipe flange connections.	Very dangerous and should be attended to immediately. Easy to locate and remedy.
Gear seizes; refuses to hold, slips, or grates and groans.	Worn or loose gears. Water or dirt in gears. Gear-case loose or dirty. Poor lubrication. Wrong adjustment. Broken tooth of gear, loose key, or bushing. Loose	Overhaul gear, clean, lubricate, and adjust. If any loose, worn, or broken parts, they should be renewed.

Trouble	Cause	Remedy
	piece in gear case. Broken ball in thrust bearing. Gear out of line with engine.	
Governor fails to work. Engine races, cuts out too soon, or stops. No compression. Runs first fast, then slow. Suddenly speeds up or slows down. Picks up badly under load.	Springs too strong or too weak or broken. Arms of weights stuck or bent. Toggles, or sliding collar, stuck or jammed. Loose parts causing backlash. Mechanism out of true or badly adjusted. Springs rusty or parts gummed from old oil or paint.	Clean thoroughly and oil well. Look after springs and see that all parts move readily and freely but are not loose.
Ignition bad. Engine runs sluggishly and unevenly. Sometimes runs jerkily. Will start on priming charge but not run itself. Misfires. Back explosions. Muffler explosions. Pound.	Short circuits; weak batteries. Coil burnt out or vibrator stuck. Short circuit in coil of timer. Engine timed so that ignition takes place too late or too early. Timer contacts worn. Wires broken or insulation bad. Magneto broken, short-circuited, or belt slips. Brushes worn or dirty. Oil or water on spark-plug points. Igniter points worn or dirty. Mica packing broken or oil-filled. Igniter springs too weak or rocker	Overhaul wires and test batteries and coil. Clean vibrator. Try a new coil. Clean contacts and all connections on switch, coil, and plug. Clean plug or use new one. Clean timer and oil it well. Try on batteries without magneto. Replace brushes if worn. Try new springs on igniter. Clean spindle with kerosene. Tighten rocker on spindle. Clean mica packing or replace. If wires are wet or oil-soaked try new wire. Remember

Trouble	Cause	Remedy
	spindle stuck, bent, or rocker loose on spindle.	that most motor troubles are in the ignition.
Knocking or pounding. Any unusual sound or rattle in cylinder base or about any part of engine. Occasional loud explosions when starting or smoke blowing out from joints in crank case in two-cycle motors.	Pre-ignition. Spark too far advanced. Soot or carbon in cylinder or plug. Short circuit in timer. Overheated engine. Want of oil. Poor oil. Some part loose, cracked, or broken. Worn or dry bearings. Loose piston pin. Broken rings. Loose weights on governor or parts of governor striking engine. Choked muffler or too small exhaust pipe. Water in cylinder or base. Too weak a mixture.	Retard spark. Clean plug and cylinder. Look at rings. Test all parts for looseness. Watch timer for sparks in same. Test for short circuits. Thoroughly oil all parts. Examine for water. Try with muffler disconnected. Give richer mixture.
Loss of power, or poor speed. Sluggish running. Misfires. Back explosions. Smoke from base of engine and carburetor. Black smoke from exhaust. Blue smoke from exhaust. Failure to run even when motor starts easily.	Faulty ignition. Poor mixture. Faulty lubrication. Too much air in mixture causes base explosions. Too much gasolene causes misfires and black smoke. Too much oil causes blue smoke. Failure to turn over more than once or twice when started shows too rich mixture or some stoppage in gasolene supply, inlet valve stuck, or base	Overhaul ignition. Give more or less fuel as required. Give more or less oil. Drain and clean carburetor, pipes, and tank. Try new spring in check valve. Work the inlet valve by hand and clean with kerosene. Use a heavier grade of oil on bearings.

Trouble	Cause	Remedy
	compression leaky in two-cycle engines. Also caused by failure of check valve to seat properly in two-port engines.	
Lubrication poor or intermittent. Overheating. Sluggish running. Bad smells from exhausts. Misfires. Blue smoke. Knocking, pounding, or seizing of piston or bearings. Noise. Warm or hot bearings.	Poor oil or oil of an improper consistency. Forgetting to oil or failure to feed oil regularly. Oil-feeds choked with old oil, dirt, or water. Oil-pump (in force feed) out of order; belt or friction drive to oiler slips. Particles of grit or metal in oil. Leak in oiler tank.	Try a different grade of oil and thoroughly clean all oilers, pipes and feeds, and oil connections. Adjust feeds accurately to feed more or less as required. Try new belt or friction wheel. Test tank for leakage. Use the best oil money can buy; oil is cheaper than engines.
Misfires. Engine runs sluggishly or jerkily. Runs well a short time and then slows down and stops. Explosions in base or muffler.	Ignition or carburetor troubles. Dirty plugs, connections, or switch contacts. If engine runs slower and slower and then stops without overheating, batteries are run down. Timer dry, dirty, or worn. Igniter binds in bushing when hot. Muffler chokes up or carburetor does not feed as fast as motor requires. Tank too low or	Overhaul ignition as for troubles already described. Try a new switch, wires, or timer. Keep timer well oiled. Use new batteries. See that belt, gear, or friction on magneto drive are not slipping. Try without muffler or with cut-out open. Depress float on carburetor. Give more gasolene or less as required. Raise

Trouble	Cause	Remedy
	no air-vent. Dirt or water in pipes. Float set too low. Needle valve or throttle shakes shut.	tank. See that air-vent is free. Tighten lock nuts on valve or throttle.
Muffler troubles. Loud explosions, noises, rattle. Hissing.	Unexploded gas entering muffler and exploding by heat of same or by burning gas from next exhausted charge. Muffler choked or too rich a mixture used. Misfires. Poor ignition or leaky valves.	Slow motor down before stopping. Shut off by throttle before using switch. Use water-cooled exhaust or muffler. Clean muffler. Tighten up all muffler and exhaust connections and bolts. Use weaker mixture.
Noises and rattle around engine.	Loose nuts or bolts. Loose connections. Worn valves or push rods. Poor springs or loose small parts. Some part bent, cracked, or out of adjustment. Common trouble on make-and-break motors.	Tighten up all connections, screws, and nuts. Hold piece of wood, or hand, on various parts to determine where noise originates. Oil well. Place fibre washers under springs and wherever two pieces of metal hit or rattle against one another. Replace these washers as fast as worn out. Take up all lost motion.
Overheating. Smell of burning oil or paint. Smoke from jacket or cylinder. Boiling from radiator or pump. Pounding. Engine	Defect in water- or air-cooling system. Choked or air-locked pipes. Pump broken, jammed, or stuck. Packing around pump spin-	Renew or clean all pipes, radiator, etc. Examine pump and pump-drive. Examine check valves and clean. Tighten or re-

Trouble	Cause	Remedy
grinds and slows down or stops. Will continue to fire after current is turned off.	dle or plunger on plunger pump loose or leaky, allowing suction of air. Check valves in water-pipe stuck, worn, or dirty. Bits of metal in pump or valves. Racing engine. Spark too much retarded. Not enough lift to exhaust valve. Too much gasolene. Water-jacket choked with dirt or scale. Drive to pump broken or slipping. Poor lubrication. Water intake choked up.	place packing. Tighten all joints on intake water-pipe. Force water or air back through outboard inlet on marine motors. Flush water-jacket by forcing water back through it. Use an exhaust valve with longer stem. Adjust mixture and oil feeds. Stop engine at once and allow to cool gradually. Do not throw cold water on it. Oil well and turn over by hand several times before attempting to start it again. Never run a motor when it overheats.
Piston troubles. Piston pounds, seizes, or is too loose. Engine stops or is very hard to turn over.	Poor lubrication. Piston rings stuck in grooves. Broken or worn rings. Cylinder scored from using broken rings. Gummy or poor oil. Overheating. Grit or rust in cylinder. Connecting rod or piston-pin bearings worn out of true, allowing piston to cant to one side and jam. Connecting rod bent.	Pour kerosene through head of cylinder and turn engine over a number of times. Oil well and drain all kerosene from base. Examine rings and piston. Clean grooves and replace rings or use new ones. If cylinder is scored replace or have rebored. Examine connecting rod, piston pin, and bearings. Clean out all carbon

Trouble	Cause	Remedy
		and rust. If piston itself is worn have it ground down at a high-grade machine shop.
Popping in carburetor. Flame or smoke about carburetor. Flooding or overflowing of carburetor.	Too rich or too weak a mixture. Inlet valve stuck or worn or spring too weak. Spark too much retarded. Float in carburetor stuck, broken, or wrongly adjusted. Float valve loose, worn, or dirty.	Adjust mixture. Clean carburetor. Examine inlet valve and spring. Advance spark slightly. Clean float and float valve or put in new ones.
Short circuits. Misfires. Sluggish or irregular action. Sparks on wires (at night) or in timer or at vibrator. Engine stops suddenly.	Loose, dirty, worn, wet, or grease-soaked wires. Broken insulation. Poor terminal or switch connections or contacts. Batteries or wires touching. Worn-out or wet coil or magneto. Wet batteries. Some metal object or wet cloth across two wires. Dirty or worn timer. Spark plug dirty, broken, or points too close or too far apart. Some part of motor touching plug or secondary wire. Wet plug or plug packing. Broken micas in make-and-break plugs.	Go over every wire and connection, test plug, coil, timer. Try new wires, plugs, and switch. Never use metal tacks or staples over wire. Watch where sparks occur and replace such parts with new wires, etc. Adjust plug points to about 1/50 of an inch apart or, better still, use new plug. If wet, clean and soak in gasolene and dry. If wet and in a hurry soak with gasolene and burn same off, which will dry plug but may crack porcelain. Clean and replace micas.

Trouble	Cause	Remedy
Spark-plug troubles. Short circuits. Misfires. Leakage around plug.	Unsuitable plug. Plug too short or too long. Wet or moist plugs. Water, rust, or carbon on points. Core cracked or loose. Electrode nearly broken or burnt through. Points touching or too far apart. Porcelain or mica core broken or sooted. Terminal for wire loose. Packing blown out or broken, allowing leak of compression. One or both points broken. Rust or oil between thread of plug and plug hole in engine.	Clean and overhaul plug. Use a plug long enough to reach well into cylinder but not so long that it will strike piston or valves. Have thread in cylinder clean. See that wire connection is clean and tight. If points are badly worn or burnt use a new plug. If points are rusty, corroded, or sooty, smooth with fine emery cloth. Always have several plugs on hand and as soon as trouble is traced to plug replace with a new one; the old one may be repaired at any time.
Timer troubles. Knocking or pounding. Loss of power. Overheating. Irregular firing. Explosions in muffler or intake.	Badly worn timer or fibre insulation. Weak timer springs. Timer dry and stuck. Incorrect timing. Timer loose on shaft. Timer control rods bent, loose, or out of adjustment. Badly worn crank shaft, cam, cam shaft, gears, push-rod, or any valve trouble. Poor mixture which ignites slowly.	Clean and oil timer. Take up lost motion and, if necessary, try a new timer. Adjust so that contact is made just after end of compression stroke when spark is retarded. Look over rods, gears, shafts, etc. Replace any weak or worn springs and any old, worn fibre.

Trouble	Cause	Remedy
	Cam-shaft gear badly set, worn, or a tooth chipped or broken.	
Valves. Slow action. Loss of compression. Misfires. Sluggish running. Noisy exhaust. Light knocking.	Sooty or gummy deposits on stems or springs. Spindles bent, broken, or rough. Spring too strong or too weak. Pitted or scored valves. Wear of cam, gear, push-rods, tappets, valve stems or feet, or a cotter-pin in same which is loose, worn, or broken. Also hole for cotter-pin being worn oval or oblong. Not enough or too much lift. In case of automatic inlet valve, leak in cylinder or by piston, thus preventing suction from opening valve.	Clean valve stems by free use of kerosene while operating same by hand. If pitted, worn, or scored, the valve should be ground. If stem is bent get a new valve. New springs are a great help. New pins and feet, if old are worn, will make a great improvement. See that all lost motion is taken up but that the push rod or tappet is *not* continually bearing against the valve stem. Test your valves now and then to see that they are properly timed; the variation of 1/32 of an inch in the piston travel as compared with valve opening or closing will add or detract a lot of power from the motor.
Water in crank chamber. Water in carburetor. Loud explosions. Steam from exhaust. Slow or ir-	Leaky joints in jacket, at head, or other packed joints; around pet-cocks or priming cups. Water	Provide a strainer in pipe line. Protect tank and carburetor from rain. Draw off a small lot of gaso-

Trouble	Cause	Remedy
regular operation. Failure to start. Misfires. Back fires.	may get into gasolene from waves, spray, or rain. It often condenses on inside of tank or base or in carburetor in damp or foggy weather. When motor is running evaporation of gasolene causes intense cold on carburetor and the moisture thus accumulated may be drawn into cylinder.	lene from carburetor before starting motor. Drain base of engine thoroughly. Examine cylinder for leaks by filling jacket with water and looking inside while cylinder head is removed. Put new gaskets and packings on all joints. Wipe off carburetor when running if water collects.

CHAPTER IX

Glossary of Alphabetically Arranged Technical Terms used in Connection with Gasolene Engines, with Explanations.—Various Useful Tables; Heat Value of Fuels; Size and Capacity of Tanks; Iron-pipe Sizes; Drill Sizes for Screw Holes; United States Standard Screw Threads; Cap-screw Sizes; Finding Surface and Volume.

Glossary of Technical Terms

Accelerator—Any attachment or device for increasing speed.

Advanced Spark—An electrical spark produced to ignite a charge of gas in a motor before the piston reaches the upward limit of its compression stroke.

Air Lock—A gathering of air in a pipe which prevents the flow of liquid through the same.

Annular—Pertaining to or in the form of a ring.

Annular Bearing—A bearing in the form of a ring.

Annular Opening—A ring-shaped opening.

Ampere—A unit of electrical measurement nearly analogous to quantity.

Ampmeter (*Ammeter*)—An instrument for indicating or measuring amperes.

Armature—A wire coil around an iron core used in producing electricity between two magnets, as in a dynamo.

Atmosphere—The weight, or pressure, of air, equivalent to 15 pounds per square inch.

Babbitt—A composition of various soft metals used as bearings to overcome friction. Bearings made from babbitt.

Backfiring—The backward or premature explosion of a gas engine.

Baffle Plate—A plate or partition to turn or stop the flow or force of gases or other matter.

Balance Weight—A weight attached to a crank, shaft, or wheel, to balance the explosive force of the motor and lessen vibration, as well as to overcome the tendency to a dead centre.

Ball Bearing—A bearing in which revolving steel balls aid in overcoming friction.

Ball Cage—A metal cup, ring, or recess, holding the balls in a ball bearing.

Ball Check—A check valve in which a ball fits over the opening, in place of a regular valve.

Ball Pein—The round end of a machinist's hammer.

Ball Race—Hardened steel washers, or disks, against which the balls bear in a ball bearing.

Bearings—The parts on which a revolving surface rests, or through which it passes in contact.

Bed—The surface to which a motor is fastened by its bed plate.

Bed Plate—The flat surface at the base of a motor used to attach the engine to its bed.

Bell Crank—An angular crank transmitting power, or pull, at right angles.

Bevel Gear—Cog-wheels, or gears, with sloping faces for transmitting power at an angle.

Binding Post—The post, or metal object, to which electrical wires are fastened.

Boxes—The metal casings which contain, or hold, bearings in place.

Brasses—Bearings of bronze or brass used in place of babbitt.

Break Spark—An electrical spark produced by interrupting or breaking an electrical current.

Breaker—An object for breaking or interrupting an electrical current.

Brushes—Metal or carbon points used to gather or transmit electricity from the armature of a magneto to the wires.

Burr—A roughened or enlarged edge, or end, of a bolt, shaft, pipe, or other metal object.

Bushing—A cylindrical shell or casing to reduce a hole in a pipe, wheel, or other object or to enlarge the object that passes through a hole.

Butt Spark—See *Kiss Spark.*

By-pass—The passage through which the explosive gas passes from the base to the firing chamber of a two-cycle motor.

Cam—An irregular or variously shaped piece attached to a shaft and so designed as to transmit a varying motion.

Cam Gear—The gear used to operate a cam.

Cam Shaft—The shaft, or spindle, carrying a cam.

Calorific Power—The power actually contained in a unit of heat.

Calorific Value—The number of thermal, or heat, units contained in a certain quantity of fuel.

Cap Screw—A form of machine screw, or bolt, having a square or hexagonal head.

Carburetor—A device for so combining or mixing liquid fuel with air as to produce an explosive or combustible gas.

Castellated Nut—A nut with grooves on its top, to hold cotter pins.

Catalytic Ignition—Ignition by the use of spongy platinum which becomes incandescent in contact with coal-gas or carbureted air.

Centrifugal Governor—A device which regulates the speed of an engine by the centrifugal force of weights operating through springs or other devices.

Centrifugal Pump—A pump which operates by a revolving fan or wheel within a casing, and which forces water or other liquids by centrifugal force.

Check Valve—A valve so constructed that the valve lifts or opens to the pressure in one direction, but closes or seats when pressure is exerted in the opposite direction.

Choking—The failure of a motor to operate properly through the surplus of oil, fuel, carbon, or restricted passages in the exhaust.

Clearance—The space between the top of piston at its upward limit and the interior of the top of the cylinder; space between any two objects.

Clutch—A device for holding motion or power between the motor and the mechanism to be operated and which may be thrown off or released at will.

Coil—Wire wound about an iron core used to create a greater intensity in the electrical current.

Columbia Locknut—A form of nut provided with a tapered, threaded bushing within a nut; so designed as to contract or grip the thread upon which it is screwed and thus obviate slipping or working loose.

Combustion Chamber—The chamber or space in the cylinder, or connected thereto, in which the gas is ignited or exploded.

Commutator—A revolving or oscillating object connected to the wires of an armature and through the action of which the electricity is transferred by brushes to the wires. Also applied to timers.

Compression Stroke—The stroke of a piston which compresses the gas in the cylinder and at or near the limit of which the ignition and explosion take place.

Compression Cock—Same as *Relief Cock.*

Condenser—Numerous sheets of tin-foil placed in an induction coil and connected to wires across the interrupter. Designed to reduce primary sparking at the contacts and to increase the current.

Connecting Rod—The arm or rod connecting the piston with the crank shaft.

Constant Oil Feed—A device for constantly feeding oil while the machine is in operation. A force-feed oiler.

Contact Points—The points through which an electrical contact is made. The platinum points of the vibrator or of the electrodes on a make-and-break igniter.

Controller—A device for controlling any mechanism.

Cotter Pin—A metal pin with the two ends bent around so as to lie close together. When placed in a hole the ends are separated, thus preventing the cotter from slipping out.

Counterweight—The same as *Balance Weight.*

Counterbalance—The same as above.

Coupling—Any device for connecting two pipes, rods, or shafts.

Crank—The offset portion of a shaft to which the connecting rod is attached and through which power is transmitted to the shaft.

Crank (*Starting*)—The crank or handle for turning over or starting the fly-wheel of the motor.

Cranking—The operation of turning over the fly-wheel of the motor by hand to start the engine.

Crank Case—The case or recess within which the crank revolves.

Crank Shaft—The shaft bearing the crank.

Cross-head—The piece to which the connecting rod is attached and to which the piston rod is also fastened, and which slides in guides, thus transmitting straight linear motion to a crank by allowing the connecting rod to oscillate on a pivot through the cross-head.

Current-breaker—A device for interrupting or breaking the current of electricity to produce a spark.

Cut-out—A device for allowing the exhaust to pass directly into the air without going through the muffler.

Cylinder—The portion of the motor which contains the piston and within which the explosion takes place.

Cylinder Ribs—Metal ribs, or flanges, cast upon the cylinder's external surface to radiate heat and cool the cylinder in air-cooled motors.

Cycle—A certain period of time within which the same events occur *regularly.* As applied to gas engines it is practically equivalent to "stroke" and is one-half a revolution of the fly-wheel, approximately.

Cyclic Phases—The phases or changes in operation during each cycle of a motor.

Dead Centre—That portion of a revolution during which the piston cannot transmit motion to the crank; the upward and downward limits of the stroke.

Deflector—The projection from the top of the piston in two-cycle motors designed to prevent the inrushing gas from passing across and mingling with, or escaping with, the exhaust and to direct its course toward the top of the cylinder.

Diaphragm—A thin plate or partition, usually flexible.

Die—A tool for cutting male screw threads on rods or pipes.

Die Stock—The handles and holder for holding a die when using it.

Differential Gear—A combination of gears, or wheels, so arranged that motion may be transmitted to different speeds or powers, or where the resistance is unequal the power exerted may be equalized.

Differential Cam—A cam transmitting varying motions or powers.

Differential Piston—A piston composed of two pistons of different sizes and operating together to perform separate duties.

Distillate—Denatured alcohol or similar fuels.

Distributor—A device for distributing anything. In connection with motors it is usually applied to a form of electrical device which distributes the ignition current to the various cylinders, but is also applied to devices for feeding oil or to an arrangement for leading the charges of gas to various cylinders (see Elmore motor).

Dog—A mechanical appliance for transmitting certain motions.

Dowell—A pin or key used to hold two pieces or parts together.

Drop Tee—A pipe fitting in the form of a tee but provided with a bracket or flange for fastening to a wall or other object.

Drop Ell—A pipe elbow with bracket as above.

Dynamo—A machine for generating electricity through the revolution of an armature between electro-magnets.

Dynamometer—A device for ascertaining the power necessary to operate a machine at a given speed.

Eccentric—A circular disk set on a revolving shaft with its centre out of true with that of the shaft and used to transmit reciprocating motion from rotary motion.

Eddy Current—A current or irregular flow of the gas caused by square or rough corners in the passages which prevent a free flow to or from the cylinder.

Electro-magnet—A piece of iron covered with a coil of wire. When an electrical current is passed through the coil the iron core becomes highly magnetic.

Electrodes—The two points carrying the electric current between which a spark is produced, as in a spark plug.

Exhaust—The escape of the burnt gases from the cylinder. The opening through which these gases escape.

Exhaust Valve—The valve which allows the burnt gases to escape from the cylinder.

Expansion Joint—A joint or coupling so designed as to be capable of expansion and contraction by one side sliding over the other.

Face—The smooth or flat surface of a joint or wheel.

Face Plate—A plate of metal provided with clamps by the use of which an object is held in a lathe where the surface is to be turned off or faced.

Faced Joint—A joint made by having the two surfaces ground smooth and flat.

Fan—A revolving wheel or disk provided with blades or paddles for circulating air about a motor to cool it. Applied erroneously to a propeller wheel.

Feather Vibrator—A form of vibrator of very delicate construction and capable of very rapid vibration.

Flange—A projecting surface, or ridge, usually applied to parts designed to be bolted together or attached to some other object.

Flange Coupling—A joint formed by fastening two pipes or shafts together by two flanges bolted together.

Flange Union—A flange coupling when applied to pipe.

Flash Point—The temperature at which a substance ignites.

Flexible Coupling—A coupling composed of oscillating parts so designed as to allow the shaft to revolve even when the two parts are at an angle.

Flexible Elbow—An elbow constructed as in the above.

Flexible Joint—Same as above, but more often applied to small rods, etc.

Flexible Union—A union for connecting pipe constructed with parts which permit it to be set at varying angles.

Float Feed—An arrangement by which the flow of a liquid is regulated by a valve operated by a float.

Flooding—An excess of gasolene or other liquid fuel in an engine.

Fly-wheel—The large wheel at the end of the shaft used to carry the momentum of the shaft beyond dead centre and to minimize vibration.

Four-cycle—The operation of a motor in which an explosive impulse occurs only on every other revolution of the fly-wheel or on every fourth stroke.

Friction Clutch—A clutch in which the power or motion is held and transmitted by frictional resistance.

Gap—The space through which a spark will pass between two electrodes or terminals.

Gasket—A ring of material, or packing, placed between two surfaces to render the joint tight.

Gate Valve—A valve which operates by a gate or partition that rises and falls in a groove or guide, thus giving a full opening; a full-way valve.

Gauge—An instrument for measuring anything.

Gear—A cog-wheel. A combination of cog-wheels. A device for transmitting power, speed, or direction through a combination of cog-wheels or "gears."

Gear Pump—A form of rotary pump in which the water is sucked in and forced out by the revolution of two interlocking gears.

Generator—An appliance for generating gas from liquid fuel and air. An instrument for generating electricity.

Gland—A ring, or thimble, of metal used to hold packing in position.

Globe Valve—A valve which operates by a circular or globular valve. seating by turning down a threaded stem or spindle.

Governor—A device for regulating power, speed, or flow. In connection with gasolene motors, a device for regulating the speed of the motor within certain limits.

Gravity Feed—The feeding or flowing of oil by gravity alone.

Gravity Oiler—An oiler operated by gravity. Not a force-feed oiler.

Grounding—Connecting one wire from an electrical generator to the ground or to the frame of the motor and using the same in place of a complete wire to the other electric terminal.

Hammer Break—A form of breaker, or interrupter, which acts like a hammer by striking upon another piece of metal.

Hammer Vibrator—A vibrator constructed heavily to give stronger and slower vibrations than other forms.

Hanger Bolt—A lag-screw with a threaded end in place of a square head and onto which a nut may be screwed after the screw itself is in place, thus avoiding removing the screw from the wood in order to remove the object held in place by the screw head.

Helical Gear—A gear wheel with the teeth cut at a certain slant or curve, which forms the part of a helix or coil.

Helical Spring—A spring made in the form of a helix; a coil spring.

High Tension—A form of electrical discharge of high amperage. The induced current in an induction coil. The secondary current.

Hit-and-miss Governor—A governor which regulates the speed of an engine by allowing the valves to lift or remain closed through the action of an arm or blade which operates at normal speed but which misses when the desired speed is exceeded.

Horse-power—The power required to lift 33,000 pounds one foot in one minute.

Hot Tube—A form of igniter in which the charge of gas is exploded by the use of a tube kept at red heat.

Hunting—The irregular action of a governor causing an engine to slow up or increase its speed at intervals.

Hydrometer—An instrument for testing the specific gravity of liquids.

Igniter—Any device for igniting the explosive charge of gas.

Igniting Device—Same as *Igniter*.

Ignition—The process of igniting the charge of gas.

Ignition Plug—A plug inserted in the cylinder and which carries the electric spark used in igniting the charge; a spark plug.

Indicator—A machine for ascertaining the action of an engine by means of a tracing on a card.

Indicator Card—The card on which an indicator forms a tracing to show the action of a gasolene motor.

Inductance—The power of inducing, or generating, electricity in a coil of wire by passing an electrical current through another coil close to but not in contact with the other.

Induction Coil—A coil for generating induced electricity.

Inertia—The tendency of an object to remain stationary when at rest and which must be overcome before it starts to move.

Inertia Governor—A governor that acts through inertia.

Inlet Valve—The valve which admits the charge of gas to an engine's cylinder.

Insulation—The protection, or covering, of electrical conductors to prevent the escape of electricity.

Insulator—Anything which prevents the electricity from escaping from a conductor.

Intake—The opening through which the fresh gas is taken into the cylinder.

Intake Stroke—The stroke of an engine's piston which draws a charge of gas into the cylinder. The suction stroke.

Jacket—The portion of a motor covering the cylinder and separated from it by a passage for the circulation of water or other cooling liquid.

Jig—A device by which any machined article may be accurately duplicated.

Journal—A bearing on a shaft.

Journal Box—The casing holding a journal.

Jump Gap—The space through which an electric spark will jump.

Jump Spark—A spark of high-tension electricity which is caused by separating the electrodes or terminals of a circuit, thus causing the electricity to leap or jump across, producing a hot spark.

Key—A square piece of metal inserted between a wheel, or similar object, and a shaft and fitting into recesses in each to prevent turning or looseness of the two parts.

Keyway—The slot or recess into which a key fits.

Kicking—Backfiring or premature explosions causing the motor to reverse its motion when starting or to "kick" backwards.

Kiss Spark—A form of make-and-break ignition in which the contact points approach gradually, press firmly together, and separate instantly. Also called Butt Spark.

Lag-screws—Heavy wood screws provided with a square bolt head.

Lead—The advance or timing of a spark to cause ignition before the limit of the compression stroke, causing the explosion to exert its greatest force just as the piston passes dead centre.

Lever—A rod or arm for increasing, transmitting, or controlling power or motion.

Liners—Thin pieces of metal for reducing or enlarging the space between two pieces of metal.

Lock Nut—A nut screwed onto a bolt above the regular nut to prevent the latter from working loose.

Lock Washer—A washer, or ring, with one side cut through and the ends slightly turned up or sprung apart. Used to place under a nut on a bolt. The turned-up edges prevent the nut from loosening or working off by the friction of the ends bearing on the under surface of the nut.

Lost Motion—Any looseness or motion which accomplishes no useful purpose and detracts from power or speed.

Low Tension—The primary electrical current either direct from a generator or battery or after being passed through a primary-wound coil.

Lubricant—Any substance that lubricates or reduces friction between moving parts.

Lubricator—Any device for distributing a lubricant.

Lug—A metal projection for attaching to another object or for bearing against another piece.

Magneto—A machine for generating electricity by means of an armature revolving, or oscillating, between two permanent magnets.

Make and Break—A system of ignition in which the spark is produced by alternately making and breaking an electrical current.

Manifold—The common outlet of several pipes or tubes.

Manometer—A gauge or instrument for determining the pressure of gases.

Mechanical Equivalent.—The power contained in a gaseous body and which must be accounted for, either as heat abstracted from it or as some form of mechanical energy. A deduction from the law that nothing in nature can be lost or wasted.

Mechanical Oiler—An oiler or lubricator operated by mechanical means.

Mechanical Valve—A valve operated by mechanical means.

Misfire—The failure of a compressed charge to ignite and explode.

Momentum—The tendency of an object to continue in motion after the power required to move it has been stopped.

Motor—Any machine for producing power or for transforming natural forces to mechanical motion.

Muffler—A device for quieting or silencing the noise of the exhaust.

Needle Valve—A valve formed by a pointed rod bearing against the circumference of a small hole.

Nipple—A short piece of pipe threaded at both ends.

Offset Cylinder—A cylinder so placed that its centre is at one side of the centre of the crank shaft.

Offset Crank—A crank placed so that its centre is out of line with the centre of the cylinder.

Ohm—A unit of electrical measurement denoting resistance dependent upon diameter, length, and material of the electric conductor. Analogous to "friction."

Oil Feed—A device for distributing oil.

Oil Pump—Any device for pumping oil.

Otto Cycle—Four-cycle. So called because the Otto engine was the first to successfully adopt this system of operation.

Packing—Any material used to prevent leakage around a moving part or between the two surfaces of a joint.

Packing Gland—A piece of metal which presses the packing into place and is held by a threaded screw or other device.

Packing Nut—A nut used to hold packing in place.

Pein—The end of a hammer used for striking.

Peining—Hammering or stretching a piece of metal by use of the "pein."

Pendulum Governor—A governing device in which the speed is regulated by the swing of a pendulum instead of by centrifugal force.

Phases—See *Cyclic Phases.*

Pick Blade—The small blade or pick of metal which lifts the valve in a pick-blade governor.

Pick-blade Governor—A governor that regulates the speed of a motor by means of a blade or pick which lifts or misses the valve stem under excessive speeds.

Pillow Block—A block or stand supporting a bearing or journal.

Pinion—A small cog-wheel. Properly a wheel with pins or posts in place of cogs.

Piston—A sliding object within a cylinder; a plunger.

Piston Pin—The pin which holds the connecting rod to a piston.

Piston Ring—Metal rings fitted loosely around grooves in a piston which by spring of the metal form a gas-tight joint with the cylinder walls.

Pitman—The same as *Connecting Rod.*

Pitting—Wearing away or corroding of metal in the form of small holes or indentations.

Planimeter—An instrument for determining the area of indicator diagrams.

Plug—In motor parlance, the *Spark Plug.*

Plunger—A piston. Any object working or sliding within a cavity made to fit its surface.

Plunger Pump—A pump operated by means of a plunger or piston.

Port—An opening through which gas is admitted to the cylinder or base of a motor.

Pre-ignition—The igniting or exploding of a charge of gas before the proper time.

Primary Coil—A coil for producing low-tension electricity but not induced current.

Primary Winding—The first winding on a spark coil conveying the primary or low-tension current.

Primary Wire—The wire used to convey the primary or low-tension electrical current.

Priming—Pouring or injecting liquid fuel into a cylinder to start the motor. Placing water in a pump to start its operation.

Priming Cup—A cup for priming, usually a small receptacle attached to the cylinder and connected with the interior by a valve or cock.

Prony Brake—A device for testing the power of gasolene motors.

Protractor—An instrument used for determining angles and degrees of a circle.

Puddle Carburetor—A form of carburetor in which the liquid fuel is in a pool or puddle instead of in a float chamber, and from the surface of which the gas is drawn.

Pyrometer—An instrument for measuring the temperature of exhaust gases.

Quadrant—Any piece of metal in the shape of a quarter circle; usually applied to the curved, notched piece which holds levers in position.

Rack—A notched, or cogged, bar operating on a cog-wheel for transmitting rotary motion to reciprocating motion or *vice versa.*

Rack and Pinion—The combination of a rack and a small cog-wheel or pinion.

Radiator—A device for giving off, or radiating, heat and through which the hot water from the cylinder jacket is passed in order to cool it.

Ratchet Valve—A valve operated by a ratchet gear instead of by cams.

Ratchet Wheel—A disk or wheel with notches or projections so formed that it will turn in one direction but not in the other by dogs or lugs dropping into the notches.

Ratio—The proportion or relation of one thing to another.

Reducer—An appliance for reducing the size of an opening or of a rod or shaft.

Reducing Coupling—A coupling smaller at one end than at the other for reducing the size of any two pipes or rods which are connected by the coupling.

Reducing Elbow—An elbow with one opening smaller than the other.

Relief Cock—A cock or valve placed in the cylinder to relieve the pressure of compression.

Ribbon Vibrator—A vibrator made with a slender or thin piece of metal to which the contact point is attached.

Ring Oiler—A device in the form of a ring which is attached to the crank shaft and serves to distribute the oil in the crank case to the bearings and connecting rod.

Ring Valve—A valve in the form of a ring or cylindrical section.

Rotary Valve—A cylindrical or conical valve which rotates or revolves on its seat instead of lifting and closing.

Ruhmkorff Coil—An induction or vibrator coil.

Scavenging—The cleansing of the cylinder of burnt gases.

Secondary Coil—An induction coil.

Secondary Current—The induced current of an induction coil.

Secondary Wire—Heavily insulated wire for carrying the secondary current.

Self-oiling—Oiling without the aid of mechanical devices.

Self-starting—Equipped with a device for starting without turni or "cranking" the fly-wheel.

Set-screw—A screw of hardened steel or other metal used to hol shaft or other object in place.

Shaft—Any revolving rod for transmitting power or motion.

Shaft Bearing—The bearing through which a shaft passes.

—A coupling for fastening two ends of sha

Shaft Hanger—A bearing for shafting attached to a frame or post for fastening to a wall, floor, or ceiling.

Shims—Thin pieces of metal placed between joints to keep the two parts separated.

Short Circuit—The passage of electricity from one point to another without passing through the conductors provided. The escape of electricity through faulty insulation.

Sight Feed—A device by which the flow of oil or other lubricant may be seen in exactly the amount and condition in which it is fed to the parts to be lubricated.

Silencer—A device for silencing the noise of the exhaust.

Sonoscope—An instrument for determining the location of vibration or "pound" in a motor.

Spark Break—The interruption or breaking of an electrical circuit to produce a spark.

Spark Coil—A coil of either the primary or induction type which intensifies the electrical current and produces a hotter and larger spark.

Spark Plug—A plug fitted into the cylinder and insulated therefrom and provided with electrodes or terminals which produce the spark.

Sparking Points—The two terminal points or electrodes from which the spark is produced.

Spindle—A round rod or bar. The tapered or reduced end of a shaft.

Sprocket—A wheel provided with teeth which fit into the links of a chain for transmitting power or motion.

Sprocket Chain—The chain used on a sprocket wheel.

Spur Gear—A form of cog-wheel or gear-wheel in which the teeth are sharp or pointed.

Street Elbow—A pipe elbow in which one end is male- and the other female-threaded.

Stud—A piece of projecting metal to which a nut may be attached; a lug.

Stud Bolt—A bolt threaded at each end so that it may be screwed into a threaded hole and a nut screwed onto the projecting portion.

Stuffing Box—A box or casing through which a shaft passes and which may be packed to prevent leakage around the shaft.

Suction Stroke—The stroke of the piston which draws the charge of *gas into the* cylinder or crank case.

Switch—A device by which the electrical current may be turned on or off.

Tachometer—An instrument for measuring the number of revolutions of a wheel or other object.

Tap—A tool for cutting female threads in nuts, holes, etc.

Taper Pin—A round, tapered pin used to hold two parts of machinery together; especially for fastening a shaft to a wheel or gear.

Templet—A pattern or guide for duplicating parts.

Terminal—The end of a wire or electrical connection.

Thermal—Relating to heat.

Thermal Efficiency—The proportion of heat utilized by the engine as indicated by the power developed as compared with the total heat contained in the fuel used.

Thermal Units—The quantity of heat required to raise one pound of pure water from 32 degrees to 33 degrees Fahr.

Thread—A spiral groove cut in a screw, or in a hole, into which a screw is fitted.

Throttle—Any device for regulating the speed of a motor by increasing or decreasing the amount of gas entering the combustion chamber.

Thrust—The forward tendency or push of a shaft when operating under a load.

Thrust Bearing—The bearing designed to overcome the friction of the thrust.

Timer—A device for interrupting and connecting the electrical circuit at certain intervals in order to produce a spark at the correct time.

Timing—So regulating the timer, or the valves of a motor, as to operate at the proper time to develop the best results.

Torque—A twisting or turning force.

Two-cycle—A form of motor in which an explosion or impulse occurs on every upward stroke of the piston or on every complete revolution of the crank shaft.

Union—A device for connecting two pieces of pipe so that they may be connected or disconnected without disturbing the rest of the pipe.

Valve—A device for opening or closing a passage.

Valve Box—The casing in which a valve moves.

Valve Cam—A cam which operates a valve.

Valve Chamber—The chamber within which the valve is placed.

Valve Foot—The lower portion of a valve upon which push-rods or cams operate.

Valve Gear—Gears for operating the valves.

Valve Port—The opening through, or beneath, a valve which is opened or closed by the action of the valve.

Valve Rod—A rod for operating a valve.

Valve Seat—The portion of the valve box upon which the valve rests when closed. In a rotary or slide valve the portion around the valve against which it bears.

Valve Stem—The spindle or shaft that connects the valve with its foot or handle.

Vaporizer—A device for vaporizing or transforming liquid fuel to a gaseous state by mixing it with air.

Vibrator—The part of an induction coil which automatically opens and closes the circuit of electricity through the coil.

Volt—A unit of measurement of electricity denoting the force of current. Analogous to pressure.

Voltage—The amount of volts produced by a battery or generator and which will flow from it when a circuit is completed.

Voltmeter—An instrument for measuring voltage.

V-motor—A form of gas engine in which the cylinders are placed at angles with one another or in "V-shape."

V-thread—A screw thread in which the grooves are angular with sharp or "V-shaped" angles.

Waste Nut—A flange or plate for fastening pipes to a floor or wall.

Water-jacket—The casing outside of a cylinder and which contains the circulating water.

Web—The thin portion of a wheel connecting the hub with the rim.

Whitworth Thread—A particular form of screw-thread differing from the ordinary threads in the shape of the grooves. The standard British thread.

Wipe Break—A form of make-and-break spark in which the spark is produced by one electrode rubbing or passing over the other.

Wipe Spark—A spark produced by a wipe break.

Wire Drawing—The pull or resistance caused by overcoming friction or pressure against moving gas, or in overcoming the resistance to a spring.

Woodruff Key—A form of key which is straight on one side but semicircular on the other. Used as a key to hold wheels or gears on a shaft where the end of the key cannot project.

Worm Cam—A cam provided with a "worm" or spiral groove or projection.

Worm Gear—A gear which is grooved in a spiral or "screw" manner instead of being provided with cogs.

Worm and Segment—A form of gearing composed of a worm gear and a sector of a cog-wheel or pinion.

Wrist Pin—The pin which holds the connecting rod to the crosshead.

APPENDIX

HEAT VALUE OF FUELS.

(The following table is given on good authority but will be found to vary considerably from many other tables.)

Fuel	Br. Th. Units per lb.	Br. Th. Units per cu. ft.
Hydrogen at 32° F	62,030	348
Carbon	14,500	...
Carbon monoxide (C.O.)	4,396	539
Pennsylvania heavy crude oil	20,736	...
Caucasian crude oil (heavy)	20,138	...
Caucasian crude oil (light)	22,027	...
Petroleum refuse	19,832	...
Anthracite gas	3,484	...
28-candle-power illuminating-gas	.....	950
19-candle-power illuminating-gas	.....	800
15-candle-power illuminating-gas	.....	620
New York City water gas (60° F. at 30 lbs. pressure,	.....	710.5 Ave.
London coal-gas	.....	668
Benzine (C_6H_6)	18,448	...
Gasolene and its vapor	21,900	690
Ethylene (C_2H_4)	21,430	1,677
Marsh-gas (CH_4)	23,594	1,051
Natural Gas, Leechburg, Pa	.....	1,051
Natural Gas, Pittsburg, Pa	.....	892
Acetylene (C_2H_2)	21,492	868
Semi-water gas	.....	185
Producer-gas	.....	150

WROUGHT IRON AND STEEL PIPE.

Table of Standard Sizes and Dimensions

Nom. inside diam. inches	Threads per inch	Actual Inside Diam. inches	Auctal Outside Diam. inches	Thickness Inches	Nom. weight per foot pounds	Internal area Sq. inches
¼	18	.36	.54	.08	.42	.10
⅜	18	.49	.67	.09	.56	.19
½	14	.62	.84	.10	.84	.30
¾	14	.82	1.05	.11	1.12	.53
1	11 ½	1.04	1.31	.13	1.67	.86
1 ¼	11 ½	1.38	1.66	.14	2.24	1.49
1 ½	11 ½	1.61	1.9	.14	2.68	2.03
2	11 ½	2.06	2.37	.15	3.61	3.35
2 ½	8	2.46	2.87	.20	3.74	4.78
3	8	3.06	3.5	.21	7.54	7.38
4	8	4.02	4.5	.23	10.66	12.73
5	8	5.04	5.56	.25	14.50	19.99
5	8	6.06	6.625	.28	18.76	28.88

DIMENSIONS OF DRILLS FOR STANDARD V-THREAD HOLES.

Diam of Screw	Threads Per Inch	Diam. of Bottom of Thread	Nearest Drill for Full Thread	Correct Size Tap Drill
¼	20	.163	11/64	3/16
5/16	18	.216	7/32	¼
⅜	16	.267	17/64	7/32
7/16	14	.314	5/16	23/64
½	12	.356	23/64	13/32
⅝	11	.468	15/32	35/64
¾	10	.577	37/64	43/64
⅞	9	.683	11/16	25/32
1	8	.784	25/32	29/32
1 ⅛	7	.878	⅞	1 1/32
1¼	7	1.003	1	1 5/32

CAPACITY OF CYLINDRICAL TANKS.

Dimensions Inches	Capacity in Gals.	Dimensions Inches	Capacity in Gals.
9×20	5 gallons	18×30	32 gallons
10×20	8 "	18×40	40 "
12×20	10 "	18×42	45 "
12×24	12 "	18×48	50 "
12×30	15 "	20×40	50 "
14×30	20 "	20×48	65 "
14×36	24 "	20×60	80 "
16×30	26 "	22×50	80 "
16×36	32 "	22×60	100 "

TABLE OF CAP-SCREW SIZES.

Diam.	Threads Per in.	Hexagon Head		Square Head		Philister Head Diam.	Round Head Diam.
		Short Diam.	Long Diam.	Short Diam.	Long Diam.		
1/4	20	7/16	1/2	7/16	5/8	3/8	7/16
5/16	18	1/2	37/64	1/2	45/64	7/16	9/16
3/8	16	9/16	41/64	9/16	51/64	9/16	5/8
7/16	14	5/8	23/32	5/8	29/32	5/8	3/4
1/2	12	3/4	55/64	3/4	1 1/16	3/4	13/16
9/16	12	13/16	15/16	13/16	1 5/32	13/16	13/16
5/8	11	7/8	1	7/8	1 1/4	7/8	1
3/4	10	1	1 5/32	1	1 7/16	1	1 1/4
7/8	9	1 1/8	1 23/64	1 1/8	1 39/64	1 1/8	...
1	8	1 1/4	1 7/16	1 1/4	1 13/16	1 1/4	...

U. S. STANDARD SCREW THREADS

(Angle of threads 60°. Flat at top and bottom for 1/8 of pitch.)

Diam. Screw	Threads Per In.	Diam at Root of Thread	
¼	20	.185	Nut and bolt head sizes are determined by the following rules, which apply to both square and hex. nuts. Short diam. of rough nut = 1 ½ × diam. of bolt + ⅛ in. Short diam. of finished nut = 1 ½ × diam. of bolt + ⅛ in. Thickness of rough nut = diam. of bolt. Thickness of finished nut = diam. of bolt − ⅛ in. Long diam. of hex. nut = short diam × 1.155. Long diam. of square nut = short diam. × 1.414.
5/16	18	.240	
⅜	16	.294	
7/16	14	.344	
½	13	.400	
9/16	12	.454	
⅝	11	.507	
¾	10	.620	
⅞	9	.731	
1	8	.837	
1 ⅛	7	.940	
1 ¼	7	1.065	
1 ⅜	6	1.160	
1 ½	6	1.284	
1 ⅝	5 ½	1.389	
1 ¾	5	1.491	
1 ⅞	5	1.616	
2	4 ½	1.712	
2 ¼	4 ½	1.962	
2 ½	4	2.176	
2 ¾	4	2.426	
3	3 ½	2.629	

To Find Surface and Volume.

Area of Rectangle = length × breadth. *Area of Triangle* = base × 1/2 height.

Diameter of Circle = radius × 2. *Circumference of circle* = diam. × 3.1416.

Area of Circle = square of diameter × .7854.

Area of Sector of Circle = area of circle × degrees in arc ÷ 360.

Area of Surface of Cylinder = circumference × length, plus area of both ends.

Volume of Cylinder = Area of section in sq. inches × length in inches and divide by 1728 to find cubic ft.

Diam. of Circle with given Area. Divide area by .7854 and extract square root.

Surface of Sphere = square of diam. × 3.1416.

Volume of Sphere = cube of diam. × .5236.

Side of Inscribed Cube = radius of sphere × 1.1547.

Volume of Cone or Pyramid either Round, Square, or Triangular = area of base × ⅓ its height.

A Gallon of Water = 231 cubic inches and weighs 8⅓ lbs. (U. S. Standard).

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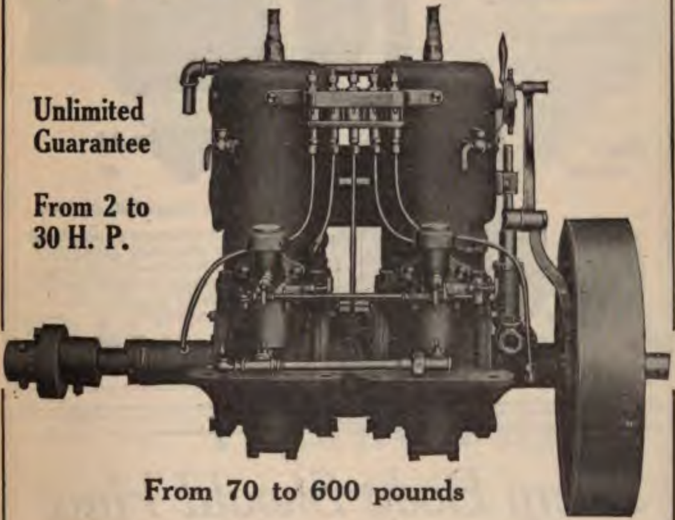

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